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All the data have been entered into the RAPS Data Bank. Hourly values are available for all point sources; locations are identified by UTM coordinates (zone 15) to within ±10 m. Area sources are assigned to a network of 1989 grid squares of variable size. The emission inventory is applicable for the years 1975 and 1976 and complements the RAPS aerometric data.

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REGIONAL AIR POLLUTION STUDY

Emission Inventory Summarization

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As part of the Regional Air Pollution Study (RAPS), data for an air pollution emission inventory are summarized for point and area sources in the St. Louis Air Quality Control Region. Data for point sources were collected for criteria and non-criteria pollutants, hydrocarbons, sulfur trioxide, particle size distribution, and heat. For area sources, data were collected on criteria pollutants, hydrocarbons and heat.

All the data have been entered into the RAPS Data Bank. Hourly values are available for all point sources; locations are identified by UTM coordinates (zone 15) to within ±10 m. Area sources are assigned to a network of 1989 grid squares of variable size. The emission inventory is applicable for the years 1975 and 1976 and complements the RAPS aerometric data.

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1.0 INTRODUCTION

1.1 THE REGIONAL AIR POLLUTION STUDY (RAPS)

The Regional Air Pollution Study (RAPS) was conceived early in 1970 to provide a rational, scientific basis for the management of air quality, as mandated by the Clean Air Act (as amended). The basic premise of the Act is that desired air quality standards can be obtained by setting appropriate emission standards. The development of Implementation Plans, called for by the Act, assumes that existing knowledge was at least minimally adequate for planning.

The basic tool for the development of air quality management is the simulation model, a mathematical description of the complex relationship between emissions, atmospheric dispersion and transformation, and ambient concentration. The development of any model presupposes: 1) a detailed understanding of the physical, chemical and meteorological process involved, and 2) availability of adequate emission data, meteorological information and measurements of ambient concentrations of the pollutants under investigation.

At the beginning of the RAPS study, a number of simulation models had been developed, but few--if any--had been verified in the field. The primary reason for this was the absence of an adequate data base, which would contain accurate, high resolution data covering a sufficiently large area. Ambient data were available with adequate time resolution--one hour or less--but the stations providing such data were typically too few and improperly spaced to cover a given area. Meteorological data were usually available only at very few points in a given area, such as an airport, where they were gathered for other purposes. Micrometeorological data related directly to ambient measurements were generally unavailable.

Emission inventories have been in existence for some years, and owing to the efforts of the National Air Data Branch of OAQPS, were being collected in a uniform, machine readable format known as National Emission Data System

(NEDS). However, the NEDS inventory contained essentially only annual data, which cannot readily and reliably be converted to hourly values over the two year RAPS program period.

Clearly, what was needed as a first step in the development of a rational approach to the management of air pollution was an extensive, detailed data base containing all these elements: emission, meteorological, and ambient data, with a resolution in time and space and an accuracy adequate to provide an input to simulation models. This became the first task of RAPS. (1)

The St. Louis Interstate Air Quality Control Region (AQCR 70) was chosen as the site for RAPS (Figure 1). The selection was based on the need to find a large city within the continental United States, which was away from oceans and mountains and which typified the coal-burning industrial nature of many urban areas, yet which lay in an extended region of rural country. Of the 33 Standard Metropolitan Statistical Areas larger than 400,000 population, St. Louis emerged as the clear choice based on the following criteria:

- Surrounding Area
- Heterogeneous Emissions
- Area Size
- Pollution Control Program
- Historical Information
- Climate

1.2 THE RAPS EMISSION INVENTORY

The emission inventory is an integral part of RAPS. With the network of Regional Air Monitoring Stations (RAMS) gathering minute-by-minute ambient and micrometeorological data (Figure 2), an emission inventory of equal quality was needed. Practical considerations make time intervals of less than one hour unrealistic. It was desirable to have the emission data based on measured values rather than calculated ones. Initially the principal pollutant of interest to the modelers was SO_2, which is intimately associated with stationary (combustion) sources.

Thus, the initial thrust was to develop a detailed point source inventory for SO_2, based on hourly, measured values. It became quickly apparent that the distribution of sources in the St. Louis AQCR made this technically feas-

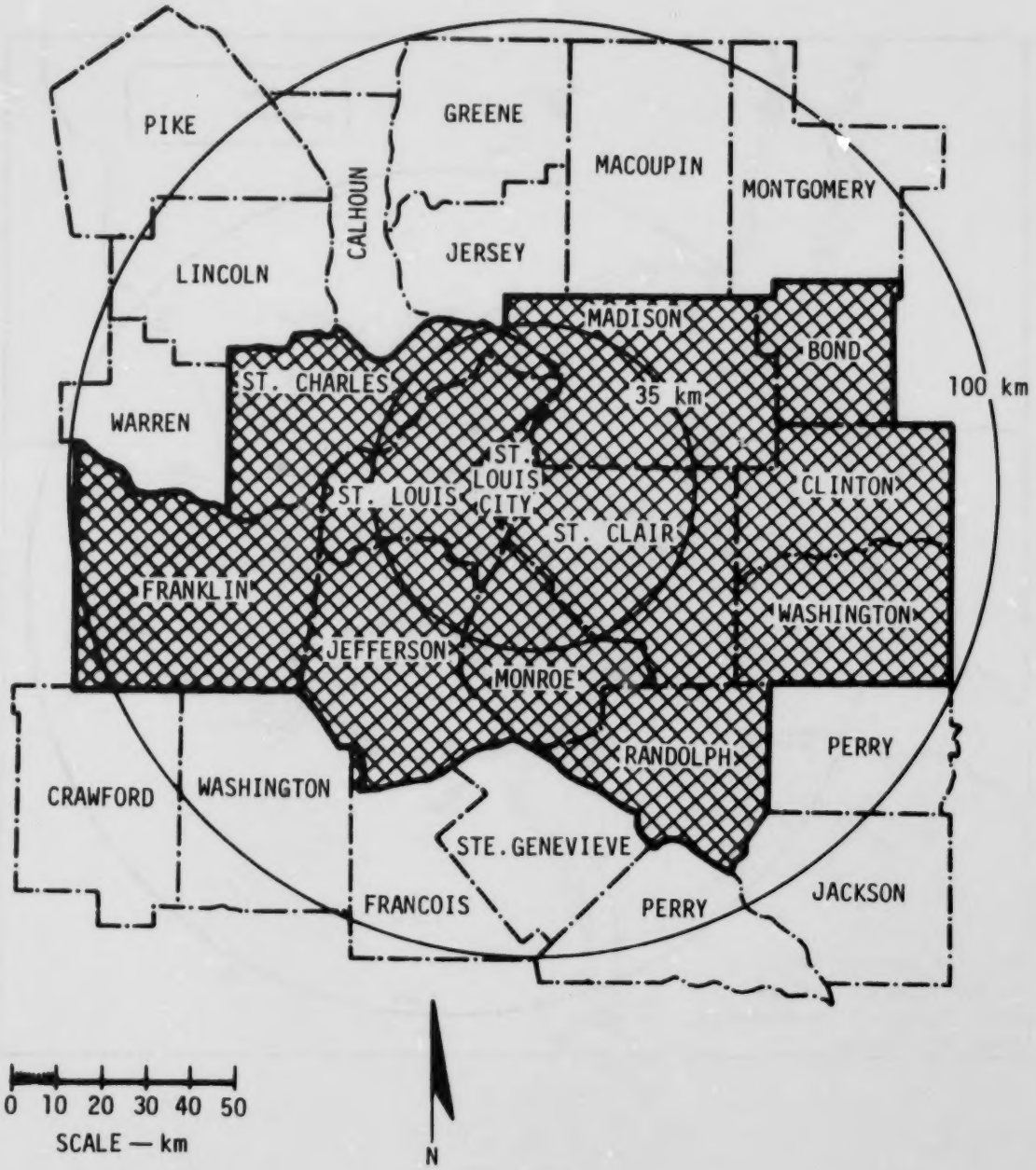


FIGURE 1. METROPOLITAN SAINT LOUIS INTERSTATE AIR QUALITY CONTROL REGION (SHADED AREAS ARE INCLUDED IN THE AQCR)

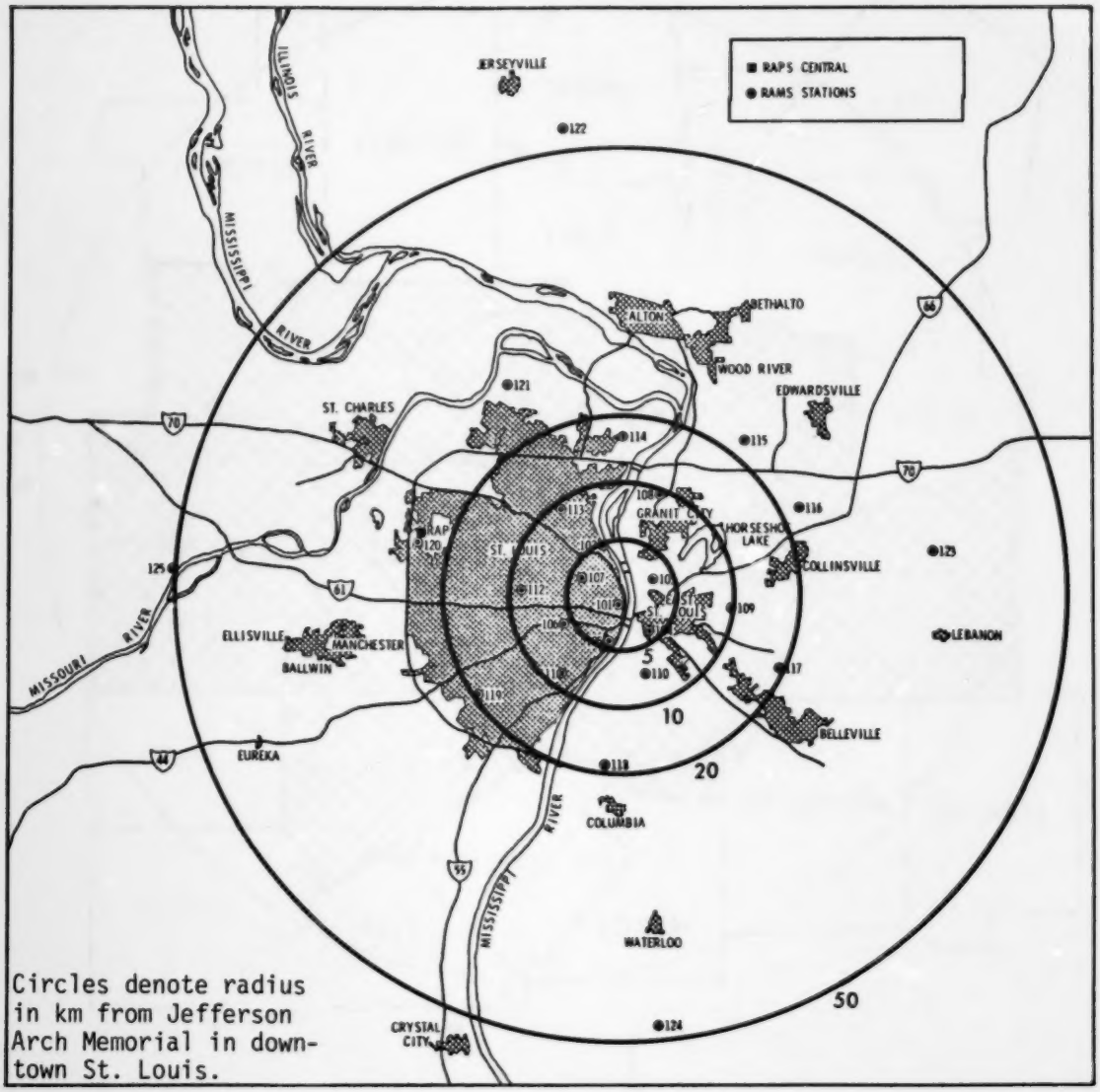


FIGURE 2. THE REGIONAL AIR MONITORING STATIONS NETWORK

ible, since a relatively small number of large sources (emitting more than 1000 tons of SO_2 annually) accounted for well over 90 percent of all emissions (Figure 3).

Arrangements were made with the companies involved to obtain the necessary data for 1975 and 1976. The data collected were not usually mass emissions of SO_2, but rather fuel consumption or production data, from which SO_2 emissions were calculated. There were several reasons for this arrangement:

1) Fuel consumption data are usually quite accurate and readily obtainable.

2) The amount of sulfur in fuel is a direct measure of SO_2 produced.

3) The emission factors for SO_2 were quite reliable.

4) Other emissions can be calculated from the same base data.

As time progressed, inventories for other pollutants were added. At this point, the following inventory data are available for the St. Louis area:

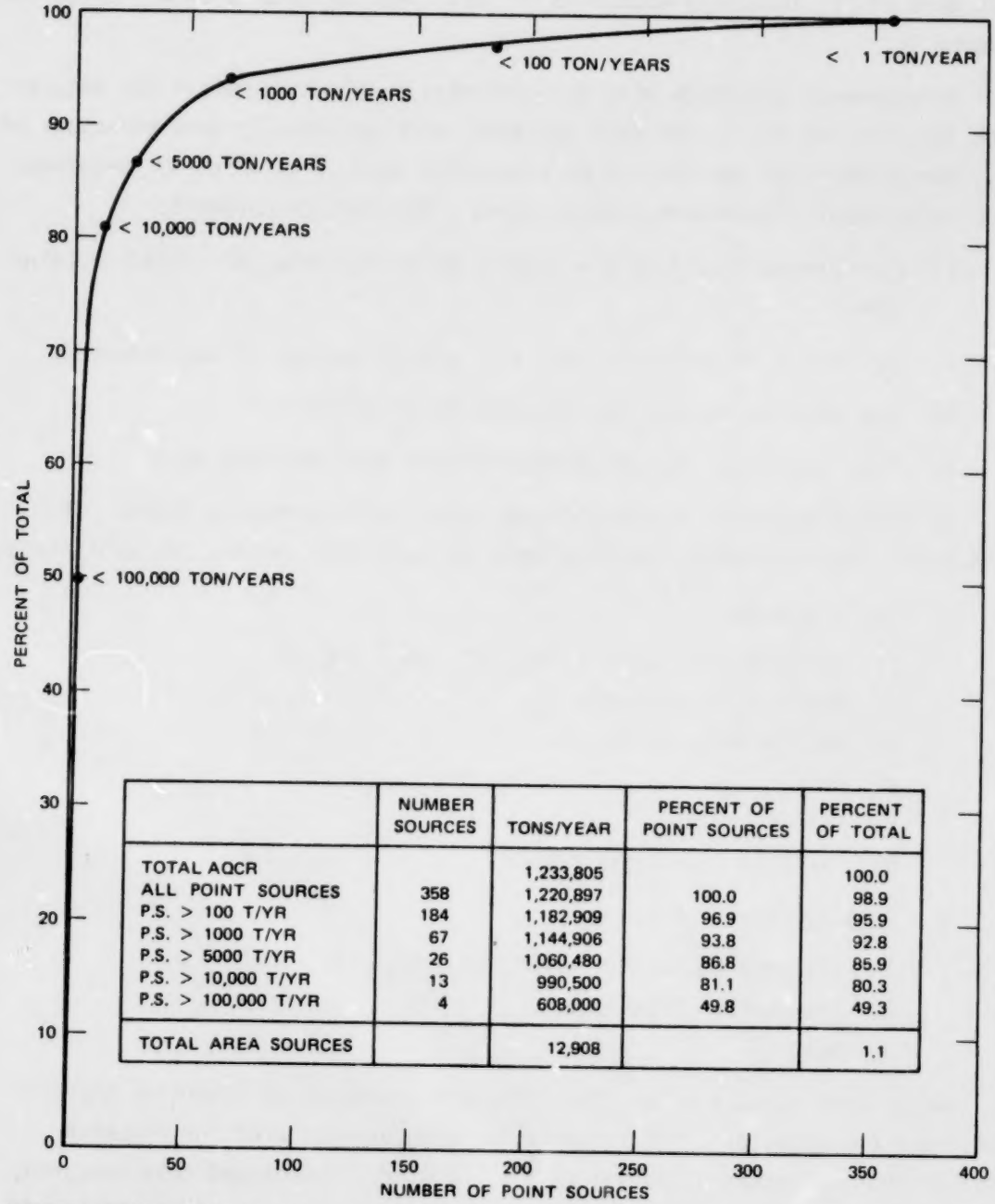
A. Point Sources

1) Criteria Pollutants - TSP, SO_2, NO_x, THC, CO
2) Hydrocarbon breakdown
3) Non-Criteria Pollutants
4) Heat
5) Sulfur trioxide
6) Particle Size Distribution

B. Area Sources

1) Criteria Pollutants - TSP, SO_2, NO_x, THC, CO
2) Hydrocarbon Breakdown
3) Heat

As a first step, a parametric study was conducted to determine the most desirable characteristics of an emission inventory gathered for research (rather than enforcement) purposes (2). The study recommended that measured, rather than calculated data be used to the largest extent possible; determined the potential uses and users of the inventory and their expected requirements; proposed a methodology for developing an inventory of the desired quality;



	NUMBER SOURCES	TONS/YEAR	PERCENT OF POINT SOURCES	PERCENT OF TOTAL
TOTAL AQCR		1,233,805		100.0
ALL POINT SOURCES	358	1,220,897	100.0	98.9
P.S. > 100 T/YR	184	1,182,909	96.9	95.9
P.S. > 1000 T/YR	67	1,144,906	93.8	92.8
P.S. > 5000 T/YR	26	1,060,480	86.8	85.9
P.S. > 10,000 T/YR	13	990,500	81.1	80.3
P.S. > 100,000 T/YR	4	608,000	49.8	49.3
TOTAL AREA SOURCES		12,908		1.1

SOURCE: NEDS Inventory (1973).

FIGURE 3. SO_2 EMISSIONS FOR THE SAINT LOUIS AIR QUALITY CONTROL REGION

suggested a data handling system; and reviewed existing emission data for St. Louis and emission models relevant to the objectives of RAPS. Cumulative plots of the number of sources vs. percent of total emissions for individual components were particularly useful in visualizing the scope of the problem at St. Louis, as was the critical review of existing emission models. A parametric examination of the effect of source location error also proved useful in designing the inventory.

2.0 POINT SOURCE EMISSION INVENTORY

2.1 DEFINITION

For the Regional Air Pollution Study, point sources were defined initially as sources emitting on the order of 0.01 percent of the total emissions of a pollutant for the whole AQCR. As a result, point sources were considered to be in excess of 100 tons per year for SO_2, 25 tons per year for particulates, 10 tons per year for CO, 30 tons per year for NO_X and 10 tons per year for hydrocarbons. In all, data were obtained from 574 sources.

TABLE 1. TOTAL EMISSIONS FOR THE ST. LOUIS AQCR (TONS PER YEAR)

	Particulates	SO_2	NO_X	HC	CO
Point Sources (% of Total)	45,224 (3%)	1,007,530 (97%)	322,730 (72%)	47,610 (23%)	164,331 (11%)
Area Sources (% of Total)	1,299,782 (97%)	30,813 (3%)	125,567 (28%)	157,204 (77%)	1,325,556 (89%)
Total	1,345,006	1,038,334	448,297	204,814	1,489,887

For the initial (SO_2) inventory, point sources were further classified into major (> 1000 tons per year) and minor (between 100 and 1000 tons per year) sources. Actual hourly emission data were collected for the major sources only. Since the preliminary survey suggested that the major sources emitted well over 90 percent SO_2, that seemed quite adequate. The actual breakdown of hourly point sources is shown in Table 2.

TABLE 2. SUMMARY OF HOURLY SOURCE DATA

Companies	Locations	Sources of Pollutants					
		PART.	SO_2	NO_X	HC	CO	HEAT
14	22	113	146	113	113	82	113

Annual data and production patterns were gathered from sources emitting between 10 and 1000 tons of any one pollutant. The breakdown is shown in Table 3.

TABLE 3. SUMMARY OF ANNUAL AND PATTERN DATA

Companies	Locations	Sources of Pollutants					
		PART.	SO_2	NO_X	HC	CO	HEAT
85	92	204	128	121	285	123	132

2.2 SENSITIVITY ANALYSIS

A sensitivity analysis was performed, using the method described by Ditto (3). This type of analysis helps evaluate the maximum permissible error of any part of the inventory, given a maximum permissible error for the whole system, thus keeping the inventory at an equivalent level of accuracy. It also provides confidence levels for the emission inventory. The analysis indicated that σ_k, the error associated with subclass k, is related to Θ, the error associated with the total amount of pollutant emitted, in the ratio of $\frac{Q}{Q_k}$, where Q is the total amount emitted, while Q_k is the amount emitted by subclass k:

$$\sigma_k = \Theta \sqrt{\frac{Q}{Q_k}}$$

The values for Θ for different confidence levels and acceptance intervals is shown in Table 4.

TABLE 4. VALUES OF Θ FOR SELECTED PAIRS (α, 1-C)

Acceptance Interval (α) \ Confidence Level (1-C)	90%	95%	99%
5%	1.58%	1.12%	0.5%
10%	3.16%	2.24%	1.0%
20%	6.32%	4.47%	2.0%

For a confidence level of 95 percent and an acceptance interval of 10 percent, Φ becomes 2.24 and the maximum allowable error σ_k for various pollutants is shown in Table 5.

TABLE 5. MAXIMUM ALLOWABLE ERROR FOR POINT SOURCES OF VARIOUS SIZES

Acceptance Interval 10%, Confidence Level 95%, Φ = 2.24%

Pollutant	Total Emissions Tons/Year	Allowable Error σ_k for Sources of		
		100 Tons/Yr	1000 Tons/Yr	10,000 Tons/Yr
Particulates	45,224	48%	15%	--
SO_2	1,007,530	225%	71%	23%
NO_X	322,730	127%	40%	--
HC	47,610	49%	15%	--
CO	164,331	91%	29%	--

These data indicate that the required accuracy for smaller sources (such as < 100 tons per year) can easily be achieved using annual data.

2.3 DATA ACQUISITION

2.3.1 Major Sources

Classically, data for emission inventories are acquired by the use of questionnaires which are either mailed out or prepared by the interviewer or inspector on the one-time basis.

The requirements of the RAPS inventory for hourly measured data for a period of two years far exceeded the normal reporting routine and required special arrangements with the management of the various facilities. Thus, personal contact with the appropriate corporate office by mail, phone and, ultimately, in person was considered essential to obtain the necessary cooperation. The request was made for access to data which would provide a basis for calculating hourly emissions. (4)

Such data could be

- stack concentration measurements
- fuel consumption records
- process data
- steam production records

These data, coupled with the necessary secondary information, such as stack gas volume, concentration of sulfur in fuel or in process materials, etc., permitted the calculation of the weight estimates of pollutant (e.g., SO_2) emitted per hour. There are two levels at which the initial information has to be gathered:

1) Management level

2) Operation level

At the management level, an "agreement in principle" was required; usually operational personnel were present at these meetings. After an agreement was reached, the details of the data acquisition were worked out with operational personnel.

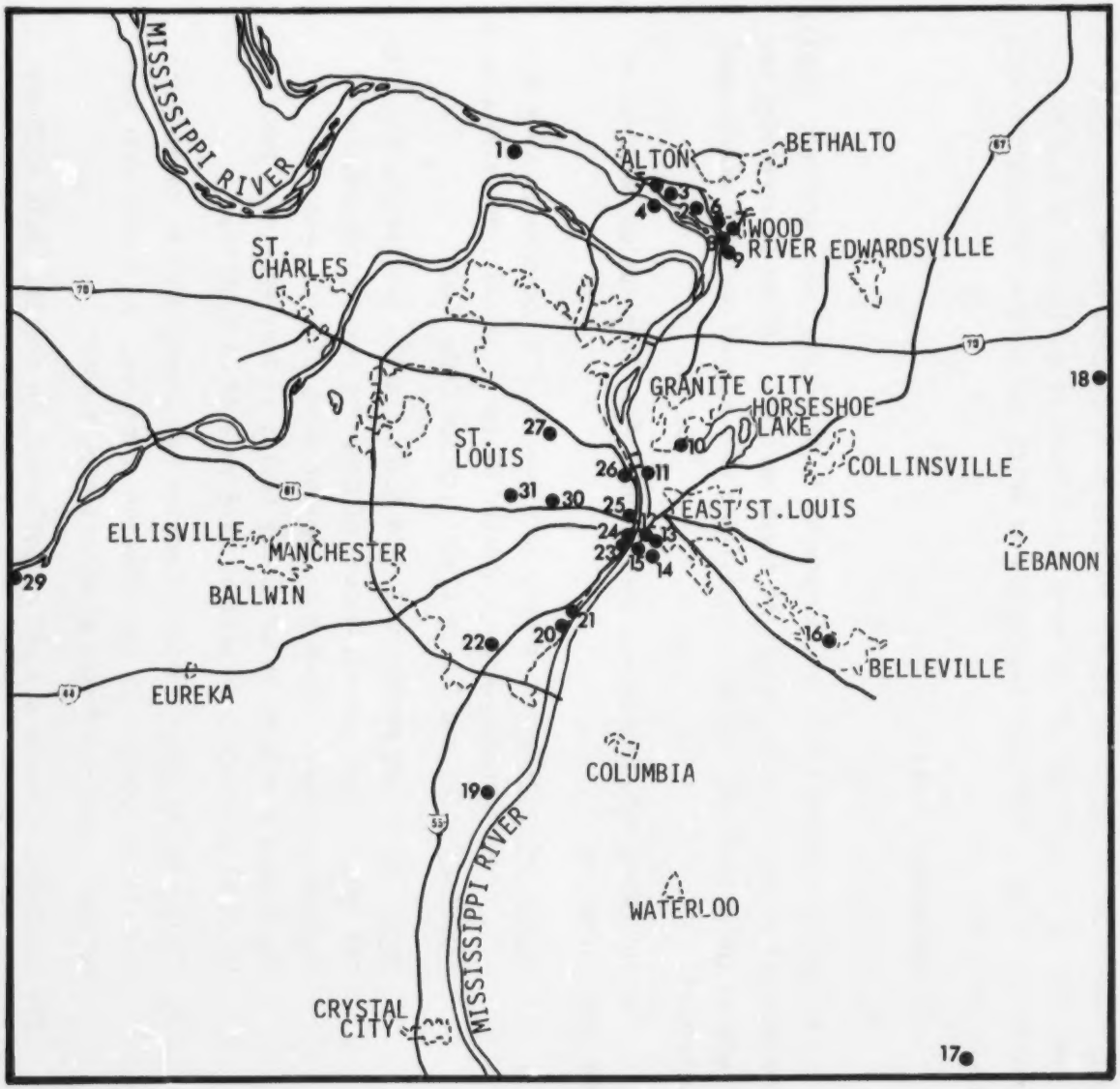
The following information was then secured from information gathered at the operating level:

1) Source Description: address, location (by UTM coordinates to $\pm$ 0.01 km), type of operation as indicated by the Standard Industrial Classification (SIC) and Source Classification Code (SCC).

2) Data: pollutant concentration in stack (rarely available), quantity and type of fuel burned, amount of steam or power produced, fuel analysis, process information (weight and analysis), etc. All of these data should be on an hourly basis; if they were not, the time interval was noted, as well as time related variability.

3) Collection of Data: data collection was arranged so as to minimize the effort required by the affected companies. As a rule data were mailed in self-addressed envelopes once a month.

The locations of major sources of pollutants in the St. Louis AQCR are indicated in Figure 4.



MAP NO.	SOURCE
1	Union Electric – Sioux
2	Illinois Power – Wood River
3	Laclede Steel
4	Alton Box Board
5	Owens Illinois Glass
6	Amoco Oil Refinery
7	Shell Oil Refinery
8	Anlin Co.
9	Clark Oil Refinery
10	Granite City Steel
11	Union Electric – Venice
12	AMAX Zinc
13	Edwin Cooper
14	Monsanto – WG Krummrich
15	Union Electric – Cahokia
16	Stag Brewery
17	Illinois Power – Baldwin
18	Highland Electric
19	Union Electric – Meramec
20	N.L. Industries
21	Great Lakes Carbon
22	Alpha Cement
23	Anheuser Busch
24	Monsanto – J F Queeny
25	Union Electric – Ashley
26	PVO Int.
27	General Motors
28	Missouri Portland
29	Union Electric – Labadie
30	Washington Univ. – Euclid Sta.
31	Washington Univ. – Campus

FIGURE 4. RAPS
MAJOR POINT SOURCES

2.3.2 Minor Sources

For point sources emitting less than 1000 tons/year, as well as those major sources where hourly data were not available, hourly emissions were obtained from operating patterns. For these sources, the following information was obtained.

1) Source description.

2) Work schedule.

3) Maximum process loads.

4) Monthly or shift fuel consumption.

5) Fuel analysis data.

The emission values were obtained and recorded as annual data, together with the operating patterns. The pattern is capable of indicating the actual operating hours, operating days (in Julian form) and weekly patterns by days. For example, the entry

D:2-48, 50-184, 186-244, 246-365, W:1-5, H:8-17

denotes the operation of a plant which normally operates Monday through Friday (W:1-5), from 8 AM to 5 PM (H:8-17), but is closed down for New Year's (D:1), Washington's Birthday (D:49), Independence Day (D:185), and Labor Day (D:245). If an hourly output for a specific hour and day is requested, the computer will first make sure the plant was operating that day, then divide the annual number by the actual number of hours of operation for a 5 day week, 9 hours a day operation, less the number of days when the plant was shut down.

2.3.3 Source Measurements

The RAPS emission inventory should ideally contain direct statements of weight of pollutants emitted from each major source as a function of location for every hour. The most direct way to acquire this information would appear to be monitoring of stack emissions.

In actuality, emissions (in terms of weight of pollutant) cannot be directly measured. Stack gas analyzers provide a measure of the concentration of the pollutant, thus requiring another measurement--stack gas volume--before the weight of the emitted pollutant can be determined. Stack gas volume, in

turn, is not measured directly, but rather is determined by measuring the gas velocity by traversing the cross-section of the stack. From the average velocity and the known dimension of the stack, the volume of the stack gases can be calculated. In addition, the molecular weight of the sampled gas has to be determined to obtain the mass flow rate. Thus, the seemingly direct and straight-forward approach to the determination of pollutant emissions by stack analysis actually consists of a number of measurements, manipulations and calculations, each of which contributes to the accuracy of the final figure. Stack sampling is time consuming and expensive; for this reason a number of representative sources were sampled and their stack effluents analyzed. (5) An attempt was made to encompass a wide variety of the larger point sources: large and medium sized power plants burning coal, fuel oil and gas; industrial boilers of different types and sizes; and industrial operations, such as catalyst recovery units in a petroleum refinery, and cement kilns, known or suspected of being major sources of pollution.

The following sources were sampled in 1975 and 1976:

Illinois Power's Wood River Power Plant, Wood River, Illinois

- Boiler No. 1, operated on gas
- Boiler No. 2, operated on fuel oil
- Boiler No. 4, operated on coal

Highland Power Plant, Highland, Illinois

- Boiler No. 3, operated on coal

Stag Brewery, Belleville, Illinois

- Boiler No. 1, operated on coal

General Motors Assembly Plant, St. Louis, Missouri

- Boiler No. 2, operated on coal

Amoco Refinery, Hartford, Illinois

- Boiler No. 6, operated on oil and gas
- Catalyst Regeneration Unit

Chrysler Motors Assembly Plant, Fenton, Missouri

- Boiler No. 1, operated on gas

Owens-Illinois Glass Company, Alton, Illinois

"A" Glass Furnace, operated on gas

Alpha Portland Cement Company, Affton, Missouri

Cement Kiln, wet process, coal-fired

U. S. S. Agri-Chem, Crystal City, Missouri

Nitric Acid Production Unit

General Motors Assembly Plant (Re-test), St. Louis, Missouri

Boiler No. 2, operated on coal

In general, the test methods specified in the Appendix of Part 60, CFR Title 40, "Standards of Performance for New Stationary Sources" were used. The methods include:

Method 1 - Sample and Velocity Traverses
2 - Determination of Stack Gas Velocity
3 - Gas Analysis of CO_2, Excess Air and Dry Molecular Weight
4 - Determination of Moisture in Stack Gases
5 - Determination of Particulate Emissions
6 - Determination of SO_2 Emissions
7 - Determination of Nitrogen Oxide Emissions
8 - Determination of Sulfuric Acid Mist Emissions

Serious problems were encountered with stack gas velocity measurements using Method 2. Using mass balance methods as a check, it became apparent that the values obtained with an S-type Pitot tube, used in accordance with Method 2, were high by amounts ranging from 8 to 78 percent. Reproducibility was adequate, and repeated calibration of the Pitot tube indicated that correct readings were obtained. A careful check of the literature indicated that high readings had been observed by other investigators. Burton (6) indicated that values of 104 to 150% of the rated value can be obtained. Grove (7) presented data indicating that, (a) significant errors are always positive, and (b) they can be very large. The most common source of errors is due to cyclonic flow, unfortunately a fairly common occurrence in power plant stacks, where "double entry" stacks (two boilers feeding one stack) are frequently used.

A comparison of measured and calculated flows is shown in Table 6. The flow rate was calculated from known fuel consumption, fuel composition and excess air data. The values obtained using flow rates based on mass balance show a much better agreement with values obtained from emission factors, than those based on Pitot measurements.

TABLE 6. COMPARISON OF SO_2 EMISSIONS BASED ON CALCULATED AND MEASURED FLOW RATES

Location	Weight of SO_2 Produced, Based On		
	AP-42 Emission Factor	Mass Balance	Measured Gas Flow
Wood River #1 (oil)	153 lbs/hr	178 lbs/hr	217 lbs/hr
Wood River #4	5245	5104	7035
Highland Power	414	433	658
Stag Brewery	75	82	125
General Motors	479	472	546
Amoco (boiler)	309	-	320
(catalytic cracker)	708	-	354

For this reason, calculated flow rates were used whenever there was an indication of non-linear flow in the stack, as indicated by the fact that turning the Pitot tube 90° on axis did not give a zero reading on the manometer.

An alternate method was used for determining sulfuric acid mist. The current standard method for SO_3 in stack gases is EPA Method 8 (CFR 40, 60.85, Appendix-Test Methods). In this method, the sample of stack gases is drawn through a series of impingers. The first impinger contains 100 ml of 80% iso-propanol; the second and third 100 ml of 3% hydrogen peroxide. There is a filter between the first and second impinger to retain entrained particulates. The contents of the impingers are analyzed for sulfate using the barium perchlorate-thorin method.

Recent work cast doubts on both accuracy and reproducibility of Method 8. The method assumes that only SO_3 (sulfuric acid mist) will be retained in the first impinger and filter (both of which are analyzed together). However, Hillenbrand (8) found that substantial amounts of SO_2 are retained in the first impinger, some of which is subsequently oxidized to SO_3, thus contributing to

high results.* For this reason a different technique was used, which was first described by Goksøyr and Ross (9) and subsequently verified by Lisle and Sensebaugh (10). The method is generally referred to as the Shell method. It is based on the condensation of sulfuric acid mist at temperatures below its dew point (but above the dew point of the water) in a condenser backed up by a fritted glass filter. The condensate is washed out and titrated.

Data presented in references 9 and 10 indicate that adsorption of SO_3 is essentially complete, repeatability is excellent, SO_2 in concentrations up to 2000 ppm does not interfere and a precision of $\pm$ 0.3 ppm of SO_3 can be readily attained.

The method was then evaluated in the Air Monitoring Center laboratories. The results of the evaluation indicate an average 100.0 $\pm$ 6.5% recovery with no significant interference from any of the variables tested (11).

Using the most reliable available results, experimental emission factors were calculated for SO_2, NO_x, CO, HC, and particulates for the sources tested. These emission factors are compared in Table 7 with the standard emission factors from AP-42.

Even though relatively few source tests have been run, certain conclusions can be drawn from the results obtained:

1. Determinations of stack gas volumes according to EPA Method 2 is uncertain. Incorrect results are obtained in a high number of cases, since the basic assumption of laminar flow, parallel to the walls of stack, frequently does not occur.

2. Engineering calculations of mass flow, based on ultimate analysis of the fuel and determinations of the excess air in the stack gases, give reasonably accurate results. This is confirmed through sulfur balance calculations. For example, the average experimental emission factors for SO_2 for coal burning installations come out to 38.75$\underline{S}$ compared with 38$\underline{S}$ suggested in AP-42.

3. The emission factors in Table 7 are applicable only to the specific installations for which they were obtained. However, definite patterns

---

* A recent revision of Method 8 (F. R. 18 August 1977) eliminates this problem.

TABLE 7. COMPARISON OF AP-42 AND EXPERIMENTAL EMISSION FACTORS

		AP-42 EMISSION FACTORS					EXPERIMENTAL EMISSION FACTORS				
	SCC CODE(1)	SO_2	NO_X	PART	CO	HC	SO_2	NO_X	PART	CO	HC
Chrysler Motors - #1 (4)	10200601	-	230	-	-	-	-	235.5	-	-	-
Owens Ill.-"A" Glass Furnace(5)	30501401	-	-	2.00	-	-	2.2	552	0.58	-	-
Alpha Cement - Wet Process (6)	30500705	23.8	2.6	228	-	-	28.4	7.9	203	-	-
USS Agri Chem - HNO_3 Unit (7)	30101301	-	52.5	-	-	-	-	60.4	-	-	-
Wood River #1 (4)	10100601	-	600	10	17	1	-	105	-	2.8	-
Wood River #1 (8)	10100501	144S(2)	105	8	3	2	168S	16	1.0	0.4	0.17
Wood River #4 (9)	10100202	38S	18	17A(3)	1	0.3	37S	1.4	10.0A	-	0.02
Highland Power (9)	10100208	38S	15	5A	2	1	40S	4.1	0.4A	-	-
Stag Brewery (9)	10200208	38S	15	5A	2	1	46S	7.2	1.9A	0.3	0.14
General Motors - #2 (9)	10200209	38S	15	13A	2	1	37S	10.8	23.6A	0.7	0.03
Amoco Cat Cracker Recovery (10)	30600201	439	71	242	-	220	246	153	360	-	0.48

(1) - The Source Classification Code and associated emission factors can be found in Appendix C of AP-42

(2) - S is the percentage sulfur in fuel

(3) - A is the percentage ash in fuel; emissions before control equipment

(4) - gas fired - lbs. per 10^6 cu. ft.

(5) - gas fired - lbs. per ton glass produced

(6) - coal fired - lbs. per ton cement produced

(7) - lbs. per ton 100% acid produced

(8) - oil fired - lbs. per 10^3 gal.

(9) - coal fired - lbs. per ton of coal

(10) - lbs. per 10^3 bbl fresh feed

appear to exist, which seem to have more general validity:

a) Emission factors for NO_x for large combustion sources (utilities) appear to be too high by a variable, but substantial, margin. The experimentally obtained factors range from a low of 7.7% to 72% of the applicable AP-42 factors. For smaller sources good agreements were obtained.

b) Experimental emission factors for particulates similarly vary from 8 to 58% of the applicable AP-42 factors for installations which do not have precipitators. In the presences of the latter, their assumed efficiency becomes the determining factor.

c) Hydrocarbon and CO emissions, which are rather insignificant for combustion sources, have also been found to be less than those suggested by the AP-42 factors.

2.4 DATA HANDLING AND CODING PROCEDURES

The RAPS emission inventory is ultimately stored in the memory banks of a Univac 1110 computer at the National Environmental Research Center at Research Triangle Park, N. C. A "System 2000" data management system is used. The necessary input, editing, and basic output programs were developed. A complete User's Manual has been prepared, which describes the data handling system.

2.4.1 Data Input

The input program was designed to be similar to the National Emission Data System (NEDS) format. In the RAPS data handling system no actual emission data are recorded and stored (with a few exceptions). Instead, the files contain fuel consumption or process data, which are converted to mass emission by appropriate manipulation as part of the output program. The advantage of this system is its flexibility, since new or additional emission factors can be added without disturbing the data base.

The data were received, usually once a month, in a variety of forms. An instruction sheet was made up for each source, which details the entry method. A uniform coding form was then made out, which served as a basis for the keypunchings of computer cards.

Five different types of input cards were used: Type I was used to record hourly fuel consumption process information data. Type II was for recording stack gas pollutant concentration and stack gas volumes; hourly values of concentration and flow are on alternate fields. Type III was used to record the annual data and corresponding patterns of minor sources. Type IV was used for non-criteria pollutants (annual data). Finally, Type V was used for the recording of special emission factors for non-criteria pollutants, heat emission, etc. A typical coding form is shown in Figure 5.

2.4.2 Editing of Data

The data were edited at several levels. The coding sheets were edited visually for numerical errors. the punched cards were verified for keypunch errors. They were then checked by editing programs, which checked for syntax and proper limits of the entered values.

Every card was checked for certain "housekeeping" information, such as proper card number (1-8), source description (point, area, line) and action code (add or change).

Card I was checked for proper ID codes for State (14 or 26), County, Plant, and City (>0).

Card II was checked for Stack No. (>0), UTM zone (15 or 16) UTM coordinate for AQCR 70 (vertical between 4180 and 4330, horizontal between 640 and 770 for zone 15, 240 and 320 for zone 16) and area ID (between 1-1843, 2001-2465).

Card IV was examined for proper Method code (0-8), Pollutant name (both criteria and non-criteria, including heat emissions) appropriate Unit and Time Intervals and existing SCC number.

Card V was checked only if it is Type 3, when the program checks for correct syntax* of operating patterns.

Card VI was checked only for card number, source description and action code.

---

*"Syntax" refers to a finite system of rules determining a rational structure of operating patterns.

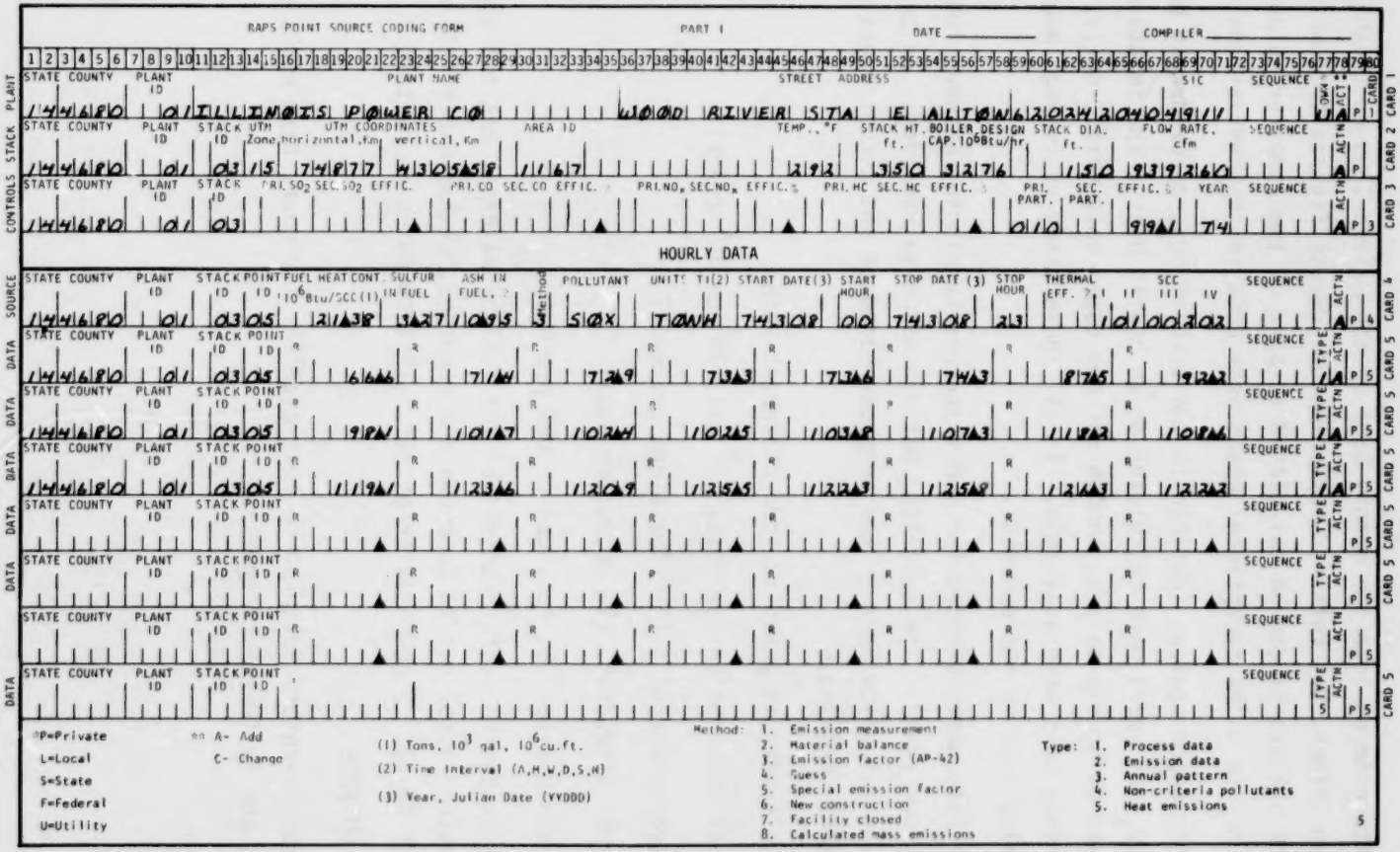


FIGURE 5. SAMPLE RAPS CODING FORM

2.4.3 RAPS Emission Inventory Calculations

The data entered into the memory bank of the Univac 1100 at EPA-NERC were not emission values, but rather consumption or process figures from which mass emissions of pollutants can be calculated as part of the computer output routine. Only in a few exceptional cases were emission concentrations recorded.

Data for major sources (defined in the case of SO_2, as producing more than 1000 tons SO_2 per year) were calculated on an hourly basis; the inputs were usually based on hourly values, though in some cases only shift, daily, weekly or even monthly data were available. In all these cases an average hourly value is calculated by the computer.

Annual data were recorded for minor sources (producing between 1000 and 10 tons SO_2 per year). The operating pattern was also recorded. An hourly average value was calculated by the computer based on the actual operating hours for each facility.

Base data were recorded in four different ways:

1. Fuel consumption (in tons, 10^3 gal, 10^3 or 10^6 cu/ft)
2. Steam production (10^3 lbs steam per hour)
3. Power production (kw or mw per hour)
4. Process rate (lb, ton, gal or bbl per hour)

In all cases the sulfur content of the fuel or material and the appropriate emission factor has to be known and recorded, either explicitly or by reference to AP-42, "A Compilation of Air Pollution Emission Factors".

2.5 SAMPLE OUTPUTS

Emission inventory data can be retrieved for any hour, day, week, month or year for the following categories:

AQCR 70	Stack
State	Point
County	SCC
Plant	

Figures 6-9 illustrate some of the outputs available for point sources. They range from hourly outputs for a single point source, to daily and yearly data for a source (Figures 7 and 8).

Results are also available on modelers tapes (Figure 9). The format of the tapes is indicated in Table 8.

****
* POINT SOURCE LISTING *
****

03: UNION ELECTRIC CO
HIGHWAY M LABADIE 63055
5200: MISSING STATE OR CITY CODE
1680: FRANKLIN CO
26: MISSOURI
SCC(1-01-002-01):EXTCOMB BOILER - ELECTRIC GENERATN- BITUMINOUS COAL - >100MMBTU PULVWET

STACK ID: 01
POINT ID: 01
SIC: 4911
AREA ID: 74
OWNERSHIP: UTILITY

UTM GRID COORDINATES
****
UTM ZONE: 15
HORIZONTAL: 688.37 KM
VERTICAL: 4270.23 KM

STACK PARAMETERS
****
STACK HEIGHT: 700 FT
STACK DIAMETER: 20.5 FT
GAS TEMPERATURE: 285 F
GAS FLOW RATE: 1600000 CFM
BOILER CAPACITY:

EMISSION METHODS
****
PART:
SOX:
NOX:
HC:
CO:

FUEL CONTENT
****
SULFUR: 2.68 %
ASH: 10.28 %
HEAT: 21.70 MBTU/SCC

CONTROL EQUIPMENT
****

PRIMARY CONTROLS	*SECONDARY CONTROLS*	*EFFICIENCIES*
PART: ELECTROSTATIC PRECIPITATOR-HIGH EFFICIENCY	PART: NO EQUIPMENT	99.5 %
SOX: NO EQUIPMENT	SOX: NO EQUIPMENT	.0 %
NOX: NO EQUIPMENT	NOX: NO EQUIPMENT	.0 %
HC: NO EQUIPMENT	HC: NO EQUIPMENT	.0 %
CO: NO EQUIPMENT	CO: NO EQUIPMENT	.0 %

* * * * EMISSIONS IN LBS * * * *

DATE	HOUR	PART	SOX	NOX	HC	CO
1/ 1/75	0	95.44	14546.08	4284.98	42.85	142.83
1/ 1/75	1	95.16	14504.04	4272.60	42.73	142.42
1/ 1/75	2	95.16	14504.04	4272.60	42.73	142.42
1/ 1/75	3	94.89	14462.00	4260.21	42.60	142.01
1/ 1/75	4	95.44	14546.08	4284.98	42.85	142.83
1/ 1/75	5	95.72	14588.12	4297.37	42.97	143.25
1/ 1/75	6	95.44	14546.08	4284.98	42.85	142.83
1/ 1/75	7	95.44	14546.08	4284.98	42.85	142.83
1/ 1/75	8	96.27	14672.20	4323.13	43.22	144.07
1/ 1/75	9	96.54	14714.25	4334.52	43.35	144.48
1/ 1/75	10	96.82	14756.29	4346.90	43.47	144.90
1/ 1/75	11	96.82	14756.29	4346.90	43.47	144.90
1/ 1/75	12	96.82	14756.29	4346.90	43.47	144.90
1/ 1/75	13	97.10	14798.33	4359.29	43.59	145.31
1/ 1/75	14	117.23	17867.30	5264.34	52.63	175.44
1/ 1/75	15	117.23	17867.30	5264.34	52.63	175.44
1/ 1/75	16	118.61	18077.50	5325.27	53.25	177.51
1/ 1/75	17	118.06	17993.42	5300.50	53.00	176.68
1/ 1/75	18	117.78	17951.38	5288.11	52.88	176.27
1/ 1/75	19	118.34	18035.46	5312.88	53.13	177.10
1/ 1/75	20	118.61	18077.50	5325.27	53.25	177.51
1/ 1/75	21	117.78	17951.38	5288.11	52.88	176.27
1/ 1/75	22	116.96	17825.26	5250.96	52.51	175.03
1/ 1/75	23	117.51	17909.34	5275.73	52.76	175.86

FIGURE 6. HOURLY POINT SOURCE LISTING

12/17/76

RAPS ST. LOUIS EMISSION INVENTORY

****
* POINT SOURCE LISTING *
****

03: UNION ELECTRIC CO
HIGHWAY M LABADIE 63055
5200: MISSING STATE OR CITY CODE
1680: FRANKLIN CO
26: MISSOURI

STACK ID: 01
POINT ID: 01
SIC: 4911
AREA ID: 74
OWNERSHIP: UTILITY

SCC(1-01-002-01):EXTCOMB BOILER - ELECTRIC GENERATN- BITUMINOUS COAL - >100MMBTU PULVWET

UTM GRID COORDINATES
****
UTM ZONE: 15
HORIZONTAL: 688.37 KM
VERTICAL: 4270.23 KM

STACK PARAMETERS
****
STACK HEIGHT: 700 FT
STACK DIAMETER: 20.5 FT
GAS TEMPERATURE: 285 F
GAS FLOW RATE: 1600000 CFM
BOILER CAPACITY:

EMISSION METHODS
****
PART:
SOX:
NOX:
HC:
CO:

FUEL CONTENT
****
SULFUR: 2.68 %
ASH: 10.28 %
HEAT: 21.70 MBTU/SCC

CONTROL EQUIPMENT
****

PRIMARY CONTROLS		*SECONDARY CONTROLS*		*EFFICIENCIES*
PART:	ELECTROSTATIC PRECIPITATOR-HIGH EFFICIENCY	PART:	NO EQUIPMENT	99.5 %
SOX:	NO EQUIPMENT	SOX:	NO EQUIPMENT	.0 %
NOX:	NO EQUIPMENT	NOX:	NO EQUIPMENT	.0 %
HC:	NO EQUIPMENT	HC:	NO EQUIPMENT	.0 %
CO:	NO EQUIPMENT	CO:	NO EQUIPMENT	.0 %

* * * * EMISSIONS IN LBS * * * *

DATE	PART	SOX	NOX	HC	CO
********	**********	**********	**********	**********	**********
1/ 1/75	2521.18	384251.99	113192.85	1131.93	3773.10

**** E N D ****

FIGURE 7. DAILY POINT SOURCE LISTING

12/16/76

RAPS ST. LOUIS EMISSION INVENTORY

****
* ANNUAL POINT SOURCE LISTING *
****

03: UNION ELECTRIC CO
HIGHWAY M LABADIE 63055
5200: MISSING STATE OR CITY CODE
1680: FRANKLIN CO
26: MISSOURI

STACK ID: 01
POINT ID: 01
SIC: 4911
AREA ID: 74
OWNERSHIP: UTILITY

SCC(1-01-002-01):EXTCOMB BOILER - ELECTRIC GENERATN- BITUMINOUS COAL - >100MMBTU PULVWET

UTM GRID COORDINATES
****
UTM ZONE: 15
HORIZONTAL: 688.37 KM
VERTICAL: 4270.23 KM

STACK PARAMETERS
****
STACK HEIGHT: 700 FT
STACK DIAMETER: 20.5 FT
GAS TEMPERATURE: 285 F
GAS FLOW RATE: 1600000 CFM
BOILER CAPACITY:

EMISSION METHODS
****
PART:
SOX:
NOX:
HC:
CO:

FUEL CONTENT
****
SULFUR: 2.89 %
ASH: 10.50 %
HEAT: 21.87 MBTU/SCC

CONTROL EQUIPMENT
****

PRIMARY CONTROLS	*SECONDARY CONTROLS*	*EFFICIENCIES*
PART: ELECTROSTATIC PRECIPITATOR-HIGH EFFICIENCY	PART: NO EQUIPMENT	99.5 %
SOX: NO EQUIPMENT	SOX: NO EQUIPMENT	.0 %
NOX: NO EQUIPMENT	NOX: NO EQUIPMENT	.0 %
HC: NO EQUIPMENT	HC: NO EQUIPMENT	.0 %
CO: NO EQUIPMENT	CO: NO EQUIPMENT	.0 %

* * * * EMISSIONS IN TONS * * * *

YEAR OF	PART	SOX	NOX	HC	CO
*******	**********	**********	**********	**********	**********
1975	388.04	62501.91	17061.27	170.61	568.71

FIGURE 8. ANNUAL POINT SOURCE LISTING

```
 74                75001 75001   JPRINT 12-16-76 18:23:38
26168003  01  744911 688.374270.23 70020.5 285
      95.44      14546.08       4284.98         42.85        142.83     920577.60
      95.16      14504.04       4272.60         42.73        142.42     917916.98
      95.16      14504.04       4272.60         42.73        142.42     917916.98
      94.89      14462.00       4260.21         42.60        142.01     915256.36
      95.44      14546.08       4284.98         42.85        142.83     920577.60
      95.72      14588.12       4297.37         42.97        143.25     923238.24
      95.44      14546.08       4284.98         42.85        142.83     920577.60
      95.44      14546.08       4284.98         42.85        142.83     920577.60
      96.27      14672.20       4322.13         43.22        144.07     928559.49
      96.54      14714.25       4334.52         43.35        144.48     931220.12
      96.82      14756.29       4346.90         43.47        144.90     933880.75
      96.82      14756.29       4346.90         43.47        144.90     933880.75
      96.82      14756.29       4346.90         43.47        144.90     933880.75
      97.10      14798.33       4359.29         43.59        145.31     936541.39
     117.23      17867.30       5263.34         52.63        175.44    1130767.30
     117.23      17867.30       5263.34         52.63        175.44    1130767.30
     118.61      18077.50       5325.27         53.25        177.51    1144070.44
     118.06      17993.42       5300.50         53.00        176.68    1138749.17
     117.78      17951.38       5288.11         52.88        176.27    1136088.56
     118.34      18035.46       5312.88         53.13        177.10    1141409.80
     118.61      18077.50       5325.27         53.25        177.51    1144070.44
     117.78      17951.38       5288.11         52.88        176.27    1136088.56
     116.96      17825.26       5250.96         52.51        175.03    1128106.67
     117.51      17909.34       5275.73         52.76        175.86    1133427.92
26168003  02  744911 688.404270.20 70020.5 285
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
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        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
        .00            .00            .00           .00           .00          .00
26168003  03  744911 688.454270.10 70029.0 285
     243.84      37163.98      10947.76        109.48        364.93    2534293.87
     244.39      37248.06      10972.52        109.73        365.75    2540027.59
     244.39      37248.06      10972.52        109.73        365.75    2540027.59
     244.39      37248.06      10972.52        109.73        365.75    2540027.59
     242.19      36911.74      10873.45        108.73        362.45    2517092.76
     244.12      37206.02      10960.14        109.60        365.34    2537160.72
     239.43      36491.33      10749.61        107.50        358.32    2488424.31
     238.60      36365.21      10712.45        107.12        357.08    2479823.78
     238.33      36323.17      10700.07        107.00        356.67    2476956.91
     238.05      36281.12      10687.68        106.88        356.26    2474090.06
     241.64      36827.65      10848.68        108.49        361.62    2511359.12
     242.45      36953.78      10885.83        108.86        362.86    2519959.66
     243.57      37121.94      10935.37        109.35        364.51    2531427.03
     236.40      36028.88      10613.38        106.13        353.78    2456889.00
     243.02      37037.86      10910.60        109.11        363.69    2525693.34
     240.81      36701.53      10811.53        108.12        360.38    2502758.56
     232.26      35398.27      10427.61        104.28        347.59    2413886.22
     221.78      33800.72       9957.01         99.57        331.90    2304946.00
     222.88      33968.89      10006.55        100.07        333.55    2316413.41
     234.74      35776.64      10539.07        105.39        351.30    2439687.87
     238.60      36365.21      10712.45        107.12        357.08    2479823.75
     239.43      36491.33      10749.61        107.50        358.32    2488424.31
     239.71      36533.37      10761.99        107.62        358.73    2491291.19
     238.88      36407.25      10724.84        107.25        357.49    2482690.62
999999
    8255.08    1258151.89     370626.03       3706.26      12354.20
ENDJOB
```

FIGURE 9. MODELER'S TAPE

TABLE 8. MODELER'S TAPE FORMAT

First Block Record - (stack parameter card)

Column	Field Size	Contents/Notes
1	1	FILLER - Blank
2-3	2	STATE - Alphanumeric * 14 = Illinois 26 = Missouri
4	1	FILLER - Blank
5-8	4	COUNTY - Alphanumeric *
9	1	FILLER - Blank
10-13	4	PLANT - Alphanumeric
14	1	FILLER - Blank
15-16	2	STACK - Alphanumeric
17	1	FILLER - Blank
18-21	4	AREA ID - Km^2 **
22	1	FILLER - Blank
23-26	4	SIC - Alphanumeric *
27-33	7	UTMH - Km
34-40	7	UTMV - Km
41-44	4	HEIGHT - ft. or m †
45-58	4	DIAMETER - ft. or m †
49-52	4	TEMPERATURE - °F or °C †
53-80	28	FILLER - Blank

(continued)

* SAROAD Station Coding Manual, APTD-0907

** Ref. 20

† Metric option

TABLE 8 (continued)

Subsequent Records per Block - (data cards)

Column	Field Size	Contents/Notes
1	1	FILLER - Blank
2-13	12	PARTICULATE - lb or kg †
14	1	FILLER - Blank
15-26	12	SOX - lb or kg †
27	1	FILLER - Blank
28-39	12	NOX - lb or kg †
40	1	FILLER - Blank
41- 52	12	HC - lb or kg †
53	1	FILLER - Blank
54-65	12	CO - lb or kg †
66	1	FILLER - Blank
67-78	12	FLOW RATE - cfm or m^3 †

† Metric option

3.0 SPECIAL POINT SOURCE INVENTORIES

3.1 HYDROCARBON EMISSION METHODOLOGY AND ORGANIC EMISSION INVENTORY

3.1.1 Point Source Total Hydrocarbon Inventory

The initial hydrocarbon point source definition was 10 tons per year as a lower limit (12). Contrasted with the SO_2 inventory, 97 percent of which are of point source origin, only about 23 percent of the hydrocarbons are of industrial (point source) origin in the St. Louis AQCR. In order to improve the accuracy an additional effort was made to include all industries emitting more than one ton of hydrocarbons per year. Total emissions were about 47,610 tons, with 37 locations emitting more than 100 tons per year. Service stations and dry cleaners are included in the area source inventory, even though emissions from individual sources can be on the order of 5 tons per year.

Emission patterns for hydrocarbon sources vary widely due to the variety of types of hydrocarbon sources. Data which were received continuously as part of the RAPS point Source Inventory were generally on an hourly basis. Hydrocarbon data from sources which produce or use coatings and solvents were accompanied with hourly use patterns based on working hours during a year. Evaporative emissions from petroleum storage were assumed to be generated on a continuous basis and were, therefore, spread equally throughout the year. With the exception of hydrocarbons from hourly combustion data, hydrocarbon emission data were collected as annual data. Data were tabulated for total hydrocarbons and non-methane hydrocarbons.

A sensitivity analysis similar to the one performed for other criteria pollutants, indicated that for an acceptance interval of 10 percent at a 95 percent confidence level, the allowable error for the subclass of 100 tons per year is 49 percent, for 10 ton sources 153 percent, and for 1 ton sources 485 percent.

Some source tests were carried out to help determine the methane/non-methane breakdown. The results, shown in Table 9 indicate that the only substantial man-made source of methane is fuel combustion.

TABLE 9. METHANE EMISSION SOURCES

Source	SCC	METHANE AS PERCENT OF TOTAL HYDROCARBON	
		Hillenbrand Ref (8)	RAPS Test Ref (12)
Petroleum Refining - Storage	4-03-002-01		nil
- Catalytic Cracker	3-06-002-01		20
Fuel Combustion - general	1-XX-XXX-XX	78	
- utility boiler, oil	1-01-005-01		74
- industrial boiler, oil	1-02-004-01		71
- industrial boiler, coal	1-02-002-09		43
Surface Coating* - Heat Curing	4-02-XXX-XX	2	30
- Air Dry	4-02-XXX-XX	0	10
Degreasing	4-01-002-XX	0	
Industrial Manufacturing	3-01-XXX-XX	0	
Coking Plants	3-03-003-XX		0

*NOTE: SCC numbers do not differentiate between heat curing and air drying.

For these source tests, samples were collected in 5 mil Teflon bags and analyzed within 6 hours of the collection time; errors due to diffusion are estimated to be less than 3 percent. An analytical technique was developed, based on a Gow Mac Series 750 gas chromatograph, which was linear with respect to carbon number and hydrocarbon concentration up to a level of 3.5×10^3 ppm as carbon. Since the content of this inventory is included in the Point and Area Source Organic Emission Inventory (Section 3.1.2), the data it contained were not included in the RAPS memory bank.

3.1.2 Point and Area Source Organic Emission Inventory

Subsequently the hydrocarbon inventory, (hereafter refered to as the "volatile organics" inventory is keeping with EPA's nomenclature), was refined and expanded to include area as well as point sources. Area sources contribute 156,204 tons per year, or about 77 percent of the total. The bulk of these emissions originate from mobile sources: 113,240 tons per year.

In addition to the development of the methane/non-methane breakdown, the organic inventory was further subdivided into five classifications (13). The primary purpose of the breakdown of organic emissions into categories was to provide emissions data for the evaluation of photochemical reaction models.

Chemical kinetic mechanisms present in air quality simulation models require some form of organic classification in order to treat the reaction processes and rates associated with their structural make-up. One such classification scheme, required in using a lumped chemical kinetic reaction mechanism approach, distributes organics in the atmosphere structurally into paraffin, olefin, aromatic, aldehyde, and non-reactive classes. This classification has been determined for organics emissions in the St. Louis AQCR. Sufficient reference data have been included to derive alternative schemes as required.

In order to make a breakdown of organic emissions into appropriate categories, their compositional analysis has to be known. Trijonis and Arledge (14) have recently compiled analytical data for organic emissions for the Los Angeles area. Although there are some differences between Los Angeles and St. Louis emissions, the report has been useful in classifying the RAPS data. Allowances were made for differences in composition in petroleum products between the two areas, and additional data were gathered for activities not present in Los Angeles, such as coking operations and the combustion of coal.

Organic emissions, divided into the five categories mentioned above, are available for all point sources based on their Standard Classification Code (SCC), and for all area sources. A typical classification is shown in Table 10. The results, summarized in Table 11, are stored in the RAPS emission inventory computer bank at Research Triangle Park.

TABLE 10

RAPS HYDROCARBON CLASSIFICATION

SURFACE COATING - AIR DRIED - Paint, Enamel

Aver. Mol. Wt. 100

NON-REACTIVES	mol %	wt %	PARAFFINS	mol %	wt %	OLEFINS	mol %	wt %	AROMATICS	mol %	wt %	ALDEHYDES	mol %	wt %
Acetone	7	4	C_4^+ paraffins	41	41				Prim.& Sec.-alkyl benzenes	6	7			
Methanol	2	1	Cycloparaffins	6	9				Dialkyl benzenes	4	7			
Partially halogenated paraffins	1	1	N-alkyl ketones	7	6				Tri & tetra - alkyl benzenes	1	2			
			Prim.& Sec.-alkyl acetates	5	5									
			Branched alkyl ketones	3	2									
			Prim.& Sec.-alkyl alcohols	13	11									
			Cellosolves	4	4									
		6			78			0			16			0

TABLE 11. SUMMARY OF TOTAL ORGANIC EMISSIONS INVENTORY BY CLASS

SOURCE CATEGORY	NON REACTIVE	PARAFFINS	OLEFINS	AROMATICS	ALDEHYDES	TOTALS
	ANNUAL EMISSIONS, TONS/YR.					
Point Sources						
Fuel Combustion	1,793	272	245	136	271	2,717
Chem. Manufacturing	-	-	-	6,702	-	6,702
Primary Metals	1,941	23	305	70	-	2,339
Refinery Operations	358	5,299	1,074	430	-	7,161
Surface Coatings	843	15,593	-	4,636	-	21,072
Petroleum Storage & Marketing	597	5,070	1,790	-	-	7,457
Solid Waste Disposal	57	22	42	5	10	136
Miscellaneous	12	-	12	-	-	24
Point Source Totals						47,608
Area Sources						
Industrial Area Sources	29	57	3	18	3	110
Residential & Commercial Heating	3,008	456	410	228	456	4,558
Vehicles, Line Sources, Exhaust	8,093	35,314	15,450	14,714	-	73,571
Vehicles, Line Sources, Evap.	1,021	15,321	5,107	4,086	-	25,535
Vehicles, Line Sources, Diesel	40	708	160	160	267	1,335
Vehicles, Area Sources	1,257	6,283	2,010	2,890	125	12,565
Railroads	127	2,237	506	506	844	4,220
River Vessels	28	498	113	113	188	940
Airports	146	686	350	248	30	1,460
Off-Highway Mobile	1,628	7,977	2,279	3,744	652	16,280
Gas Marketing	1,092	9,282	3,276	-	-	13,650
Dry Cleaning	490	148	-	7	-	645
Surface Coating	255	2,271	-	1,231	-	3,757
Area Source Totals						158,626
TOTAL	22,815	107,517	33,132	39,924	2,846	206,234

3.2 POINT SOURCE NON-CRITERIA POLLUTANT EMISSION INVENTORY

The Clean Air Act of 1970, as amended, establishes the achievement of clean air as a national goal. In pursuance of this goal, Air Quality Criteria were developed and Air Quality Standards established for five pollutants: sulfur dioxide, carbon monoxide, particulate materials, hydrocarbons and oxidants. These pollutants are frequently termed "criteria pollutants".

It is well known, however, that a large number of other substances occur in polluted air, some of which have toxic or carcenogenic properties, such as mercury, asbestos or beryllium. The Clean Air Act requires the Administrator to consider other pollutants and to determine whether they are hazardous. Such a determination is conditioned on the magnitude of the health and welfare effect; it, in turn, is a function of the occurrence of the pollutant as well as its intrinsic toxicity.

Thus, one input into these considerations is an assessment of the sources of such pollutants, as well as the pollution burden they create. For this reason, a series of studies had been performed for the Environmental Protection Agency, which were issued under the general heading of "National Inventory of Sources and Emissions" (15). In this series, some 21 compounds were examined, and emission factors were developed. Though no high degree of accuracy is claimed for these factors, they can serve as a useful basis for first approximations of the emissions in a given area.

The following pollutants are included:

- Arsenic
- Asbestos
- Barium
- Beryllium
- Boron
- Cadmium
- Chromium
- Copper
- Lead
- Magnesium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Phosphorus
- Selenium
- Silver
- Titanium
- Vanadium
- Zinc
- Benz-a-pyrene

The emission factors found in these reports were assigned to the sources extant in the St. Louis AQCR, using their SCC designation (16). The emission factors were modified to correspond to the production or consumption units used in the RAPS data base and grouped into 19 sets. A partial listing of these sets and corresponding SCC numbers is shown in Table 12.

This file is keyed to SCC numbers. When requested by the output program, the computer will calculate the emissions for any pollutant for a given source by multiplying its annual operating rate by the appropriate factor. It can also provide the total amount of any one pollutant by grid ID, county, state and AQCR. Tables 13, 14, and 15 show emissions for three sources of pollutants: coal, residual oil and iron production.

Emissions for five compounds were retrieved from the data handling system and are shown in Table 16.

TABLE 16. EMISSIONS FOR SELECTED COMPOUNDS FOR AQCR 70

Compound	Emissions (lbs/year)
Arsenic	177,985
Cadmium	5,532
Lead	1,085,027
Mercury	19,376
Benz(a)pyrene	4,437

A computer printout giving the emission of five pollutants from a single source is shown in Table 17.

3.3 SULFUR COMPOUNDS AND PARTICLE SIZE DISTRIBUTION

3.3.1 Sulfur Compounds (SO_3)

In combustion operations sulfur trioxide originates from the oxidation of sulfur dioxide in the presence of excess air. Reaction rates are negligible below 200°C, reach a maximum around 400°C and taper off to zero at 1000°C. Rapid conversion takes place only in the presence of a catalyst. The reaction has been investigated fairly extensively; most investigators agree that

TABLE 12. SOURCES OF NON-CRITERIA POLLUTANTS

SCC CODE	SET	
3-04-002-02	15	BRASS/BRONZE MELT
3-04-003-01	16	GRAY IRON
3-04-003-03	16	GRAY IRON
3-04-003-30	16	GRAY IRON
3-04-004-03	17	LEAD SMELT SEC
3-05-006-03	18	CEMENT: KILN: OIL-FIRED
3-05-006-99	18	CEMENT: OTHER/NOT CLASSIFIED
3-05-007-01	18	CEMENT MFG. WET
3-05-007-02	18	CEMENT MFG. WET
3-05-013-01	19	FRIT MFG.
3-05-014-01	20	GLASS MFG.
3-06-002-01	21	GEN. FLUID CRACKER
3-90-002-01	01	BITUMINOUS COAL (CEMENT KILN/DRYER)
3-90-004-01	02	RESIDUAL OIL (ASPHALT DRYER)
3-90-004-99	02	RESIDUAL OIL (OTHER/NOT CLASSIFIED)
3-90-005-01	03	DISTILLATE OIL (ASPHALT DRYER)
3-90-005-05	03	DISTILLATE OIL (METAL MELTING)
3-90-005-99	03	DISTILLATE OIL (OTHER/NOT CLASSIFIED)
4-02-001-01	22	PAINT
4-02-999-99	23	OTHER/NOT CLASSIFIED
5-01-001-01	24	INCINERATOR (MUNICIPAL)
5-01-001-02	24	INCINERATOR (MUNICIPAL)
5-02-001-02	24	GENERAL INCINERATOR
5-03-001-01	24	INCINERATOR
5-03-001-02	24	INCINERATOR
5-03-001-05	24	INCINERATOR

TABLE 13. POLLUTANTS IN COAL

SET	POLLUTANT	(Pounds) QUANT.	UNITS: PER
01	ARSENIC	.0029	TON COAL BURNED
	ASBESTOS		
01	BARIUM	.015	
01	BERYLLIUM	.00058	
01	BORON	.018	
	CADMIUM		
01	CHROMIUM	.0039	
01	COPPER	.004	
01	LEAD	.0022	
01	MAGNESIUM	.105	
01	MANGANESE	.0077	
01	MERCURY	.001	
01	MOLYBDENUM	.0015	
01	NICKEL	.0026	
01	PHOSPHORUS	.051	
01	SELENIUM	.0025	
01	SILVER	.001	
01	TITANIUM	.018	
01	VANADIUM	.0069	
01	ZINC	.017	
01	BAP	.000007	

TABLE 14. POLLUTANTS IN RESIDUAL OIL

SET	POLLUTANT	(Pounds) QUANT.	UNITS: PER
02	ARSENIC		
	ASBESTOS		
	BARIUM		
02	BERYLLIUM	.0007	1000 GAL OIL BURNED
	BORON		
	CADMIUM		
02	CHROMIUM	.010	
02	COPPER	.0038	
02	LEAD	.9524	
02	MAGNESIUM	.012	
	MANGANESE		
02	MERCURY	.0004	
02	MOLYBDENUM	.008	
02	NICKEL	.4048	
02	PHOSPHORUS	.072	
02	SELENIUM	.0050	
02	SILVER	.004	
02	TITANIUM	.0044	
02	VANADIUM	1.2143	
02	ZINC	.0333	
02	BAP	.000033	

TABLE 15. POLLUTANTS IN IRON PRODUCTION

SET	POLLUTANT	(Pounds) QUANT.	UNITS: PER
10	ARSENIC		
	ASBESTOS		
	BARIUM		
	BERYLLIUM		
	BORON		
10	CADMIUM	.015	TON PIG IRON
	CHROMIUM		
10	COPPER	.022	
	LEAD		
10	MAGNESIUM	.019	
	MANGANESE	.0225	
	MERCURY		
	MOLYBDENUM		
10	NICKEL	.0015	
10	PHOSPHORUS	.052	
	SELENIUM		
10	SILVER	.0001	
	TITANIUM		
10	VANADIUM	.0014	
10	ZINC	.020	
	BAP		

TABLE 17. ANNUAL TRACE EMISSIONS LISTING

R A P S S T . L O U I S E M I S S I O N I N V E N T O R Y

****
* ANNUAL TRACE EMISSIONS LISTING *
****

03: UNION ELECTRIC CO
HIGHWAY M LABADIE 6305
5200: MISSING STATE OR CITY CODE
1680: FRANKLIN CO
26: MISSOURI

STACK ID: 01
POINT ID: 01
SIC: 4911
AREA ID: 21
OWNERSHIP: UTILITY

SCC(1-01-002-01):EXTCOMB BOILER - ELECTRIC GENERATION BITUMINOUS COAL - TANGENTIAL FIRING

UTM GRID COORDINATES
****
UTM ZONE: 15
HORIZONTAL: 688.37 KM
VERTICAL: 4270.23 KM

STACK PARAMETERS
****
STACK HEIGHT: 700 FT
STACK DIAMETER: 20.5 FT
GAS TEMPERATURE: 285 F
GAS FLOW RATE: 1600000 CFM
BOILER CAPACITY:

EMISSION METHODS
****
PART:
SOX:
NOX:
HC:
CO:

FUEL CONTENT
****
SULFUR: 2.89 %
ASH: 10.50 %
HEAT: 21.8 MMBTU/SCC

CONTROL EQUIPMENT
****

PRIMARY CONTROLS
PART: ELECTROSTATIC PRECIPITATOR-HIGH EFFICIENCY
SOX: NO EQUIPMENT
NOX: NO EQUIPMENT
HC: NO EQUIPMENT
CO: NO EQUIPMENT

SECONDARY CONTROLS
PART: NO EQUIPMENT
SOX: NO EQUIPMENT
NOX: NO EQUIPMENT
HC: NO EQUIPMENT
CO: NO EQUIPMENT

EFFICIENCIES
99.5 %
.0 %
.0 %
.0 %
.0 %

* * * * EMISSIONS IN LBS * * * *

YEAR OF *******	AS ***********	TI ***********	PB **********	HG **********	BeP **********
1975	3298.51	20473.52	[illegible]	1137.42	7.96

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concentrations in flue gases range from 0.5 to 5%; absolute values tend to be below 50 ppm SO_3. In the presence of moisture SO_3 hydrates to H_2SO_4 and is normally collected in this form as aerosol droplets.

Sulfur trioxide concentrations were studied experimentally in the RAPS area (17), using the "Shell" method discussed in Section 2.3.3. The SO_3 concentrations ranged from 2.7 to 44.3 ppm, well within the range indicated by other investigators. As indicated in Figure 10, there appears to be a marked dependence on excess oxygen. The percentage of SO_3 increased with increasing oxygen up to about 9%, then dropped rapidly. This may be due to the cooling effect of large amounts of excess air. There did not seem to be any correlation with the sulfur content of the fuel nor did there appear to be any marked effect of boiler capacity on the concentration of SO_3 produced. Data are presented in Table 18.

The RMS average SO_3 emission appears to be about 1.85% of the SO_2 emission. This factor can be used to calculate SO_3 emissions based on the corresponding SO_2 emissions. Using the current figures for SO_2, this amounts to an annual emission of 18,639 tons of SO_3 per year for the St. Louis AQCR. In addition, a small amount is discharged from the five sulfuric acid plants in the area.

3.3.2 Particulate Size Distribution

Emissions of particulate materials constitute a more complex problem than gaseous emissions, since the properties of particles are determined not only by their composition, but also by their size and shape. In fact, the most important properties of particles, their effect on visibility, their life-time as suspended materials, and to a large extent, their effect on health, are all determined by particle size. On all of these counts small particles, five microns or less in diameter, are responsible for most of the observed effects.

The common methods of collection and reporting of particulate emissions do not distinguish particle size. Total particulate matter is reported on a weight basis, which biases the results in favor of large particles. Since large particles are only of local importance--they settle out rapidly--and are generally not involved in health effects since they are readily retained

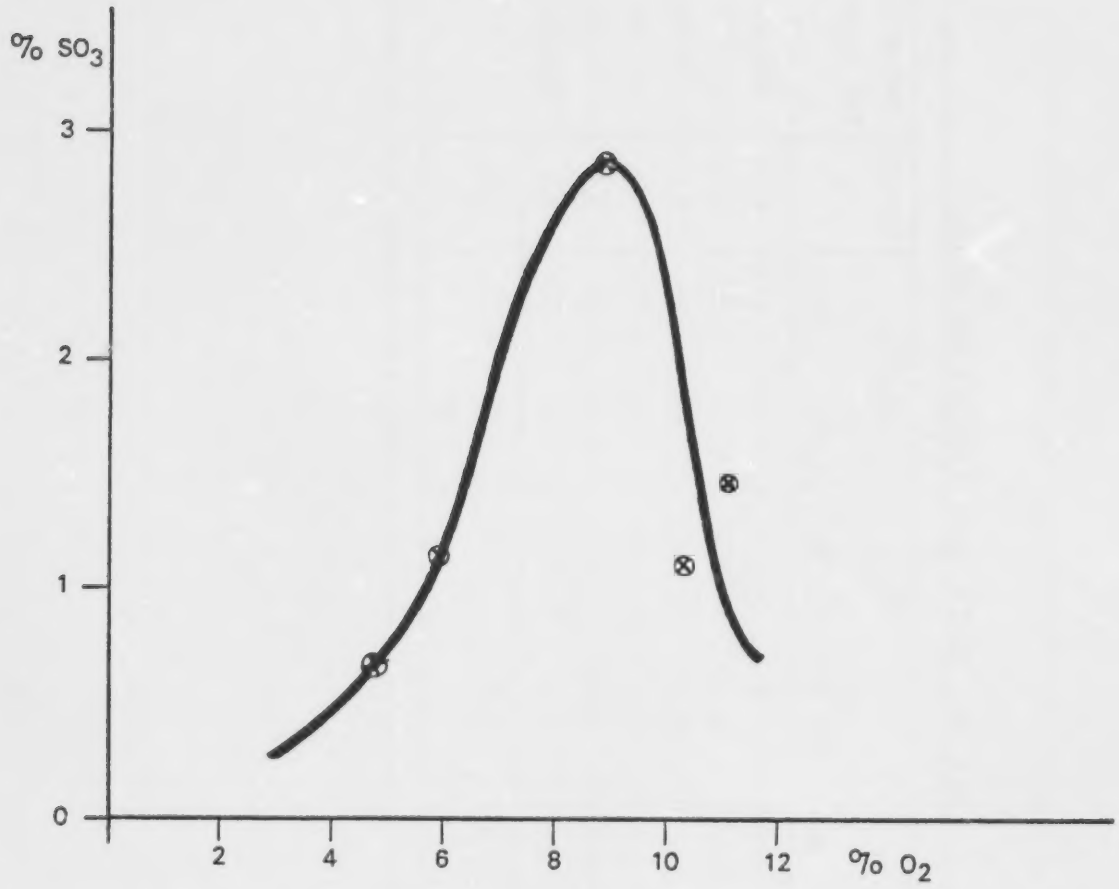


FIGURE 10. PERCENTAGE CONVERSION OF SO_2 TO SO_3

TABLE 18. SULFUR OXIDE ANALYSES AND RATIOS

	SO_2		SO_3		SO_3/SO_2		Excess O_2	Boiler Cap. lbs steam/hr	% Sulfur in Fuel
	$\frac{lbs}{10^6\ SCF}$	ppm	$\frac{lbs}{10^6\ SCF}$	ppm	Wt.	Vol.			
Wood River #1	21.5	120.5	.6	2.7	2.82%	1.49%	8.9%	450,000	.29
#4	389.5	2183.5	3.4	15.4	1.13	.70	6.0	710,700	3.21
Highland	475.0	2662.8	3.2	14.7	.69	.55	4.8	60,000	3.25
Stag	119.0	667.1	1.6	7.5	1.41	1.12	11.2	50,000	3.25
GM	349.0	1956.5	9.8	44.3	2.83	2.26	8.9	80,000	3.46
Amoco	126.0	706.3	1.4	6.4	1.13	.91	10.5	200,000	*3.00
Average	246.0	1382.8	3.3	15.2	1.69	1.17	8.4		
RMS Average					1.86				

*Weighted average

by the body's screening mechanisms, there are good reasons why particulate emission data should be reported in such a way as to provide maximum information on small particles.

There is no universally accepted definition of "fine particles", but most authors agree on a range of 3 to 5 microns as the upper limit. Particles smaller than approximately 5 microns have settling velocities in still air of the order of 0.01 cm/sec and tend to stay aloft almost indefinitely.

The most up-to-date study of fine particulate emissions is contained in EPA Technical Report entitled "Fine Particulate Emission Inventory and Control Survey" (18). The methodology contained in that report was applied to the St. Louis AQCR. In addition, samples were taken at representative emission sources using an Andersen cascade impactor.

The methodology mentioned above provides a typical size breakdown for particulate emissions from a large variety of sources. Applicable values were attached to appropriate SCC codes and placed into a SIZE file (Table 19). A similar file was established for the fractional efficiency of control equipment (Table 20). By applying the appropriate factors to the total particulate emission values contained in the RAPS inventory, emissions of particulates of a given particle size can be calculated. This methodology was incorporated into the RAPS data handling system. Thus, a size breakdown for particulate emissions can be obtained for any point source and all categories listed in Section 2.5.

In addition, experimental particle size distributions were determined (17) using an Andersen Mark I cascade impactor shown schematically in Figure 11. A summary of the results of the testing is given in Table 21. Particle size is given as aerodynamic size for spherical particles with unit density.

TABLE 19. PARTICULATE INVENTORY: SIZE DISTRIBUTION

SOURCE OPERATION	SCC - CODE	PARTICULATE SIZE RANGE (Ref. 18) microns (μ)					
		3-7 μ	1-3μ	.5-1μ	.1-.5μ	.05-.1μ	.01-.05μ
Asphalt Dryers	3-05-002-01	.190	.131	.022	.0009	.0001	0
Asphalt Vent Lines	3-05-002-02	.232	.0735	.0041	.0004	0	0
Cement Kilns	3-05-006-03	.165	.103	.0165	.0054	.0001	0
	3-05-007-01	.165	.103	.0165	.0054	.0001	0
Fertilizer Granulators and Dryers	3-01-027-06	.040	.0182	.0043	.0023	.0002	0
Iron and Steel: BOF	3-03-009-03	0	.060	.360	.578	.002	0
Elec. arc	3-03-009-05	.13	.200	.120	.210	.060	.070
sintering	3-03-008-03	.050	.027	.0056	.0024	0	0
Iron Foundry Cupolas	3-04-003-01	.065	.060	.020	.0230	.0035	.0035
Kraft Pulp Mill: B.F. Boiler	1-02-009-02	.120	.083	.018	.0080	.0003	.0001
Lime Plant: Sec. sources	3-05-016-01	.320	.350	.045	.005	0	0
	3-05-016-02	.320	.350	.045	.005	0	0
Municipal Incinerators	5-01-001-01	.050	.075	.035	.045	.010	.015
	5-01-001-02	.050	.075	.035	.045	.010	.015

TABLE 20. PARTICULATE INVENTORY: EFFICIENCY DISTRIBUTION

CONTROL DEVICE/METHOD	DEVICE ID	PARTICLE SIZE RANGE (Ref. 18) microns (μ)					
		3-7μ	1-3μ	.5-1μ	.1-.5μ	.05-.1μ	.01-05μ
No Equipment	000	0	0	0	0	0	0
Wet Scrubber: high efficiency	001	.9997	.91	.74	.38	.08	.02
med. efficiency	002	.98	.79	.57	.26	.05	0
low efficiency	003	.90	.69	.39	.14	.01	0
Centrifugal Collector: high eff.	007	.68	.43	.18	.06	0	0
med. eff.	008	.44	.17	.03	.01	0	0
Elec. Precipitator: high eff.	010	.991	.984	.977	.962	.945	.918
med. eff.	011	.93	.89	.83	.71	.59	.45
low eff.	012	.90	.75	.60	.45	.22	.12
Fabric Filter: high temp.	016	.9999	.995	.982	.967	.958	.956

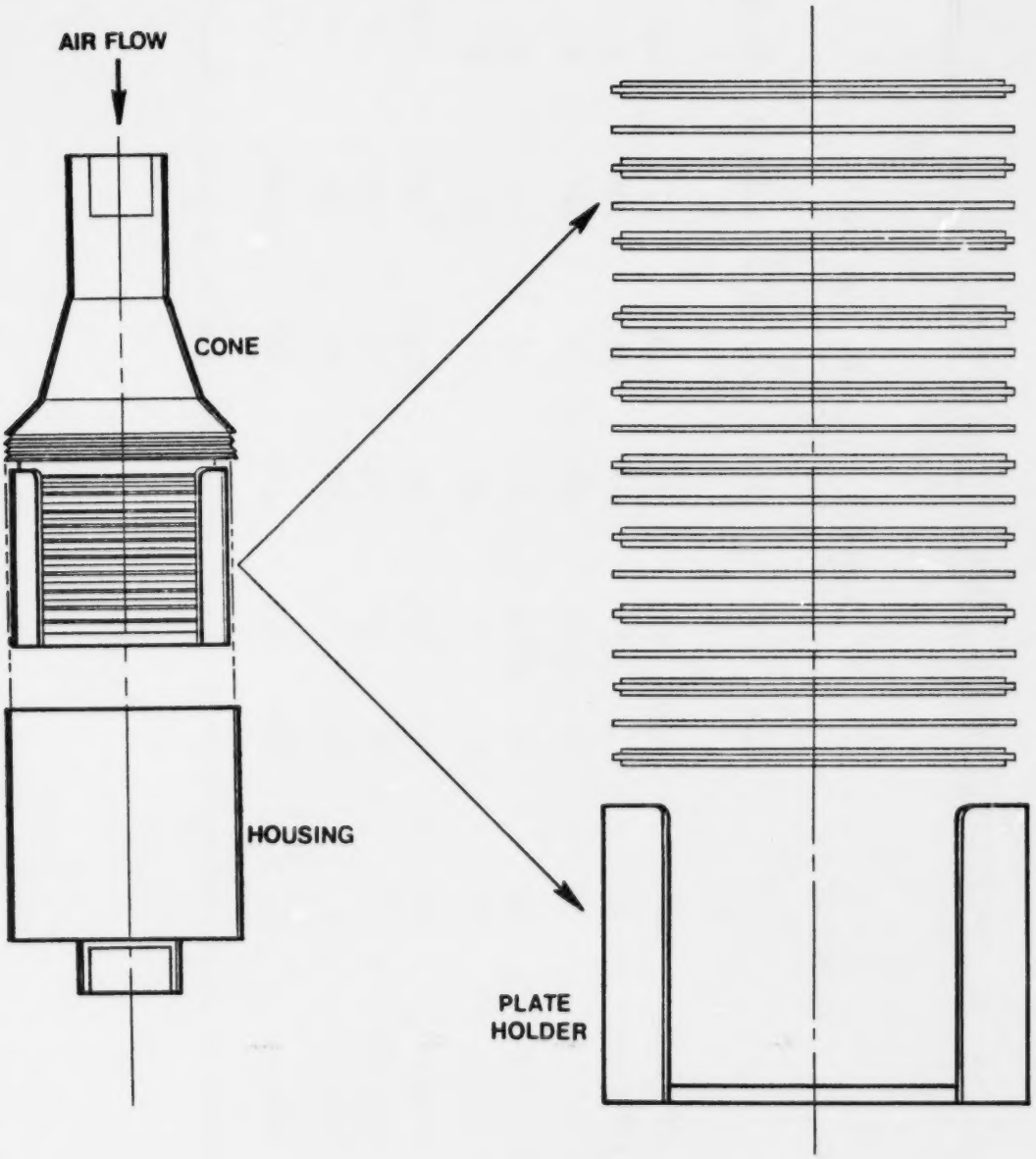


FIGURE 11. ANDERSEN STACK SAMPLER

TABLE 21. PARTICLE SIZE DISTRIBUTIONS

Source	SCC Code	% vs. Particle Size microns				
		>7μ	3-7μ	1-3μ	0.5-1μ	<0.5μ
Ill. Power - Wood River	1-01-002-02	22.5	22.8	18.5	8.3	27.9
Highland Electric	1-01-002-08	26.6	18.9	10.0	12.7	31.8
Stag Brewery	1-02-002-05	37.4	16.0	7.6	18.3	20.7
General Motors	1-02-002-09	14.3	24.4	18.5	9.2	33.6
Amoco	3-06-001-02	13.9	8.9	22.0	18.8	36.4
Owens Illinois	3-05-014-01	5.8	8.0	41.0	34.2	11.0
Alpha Cement	3-05-007-05	29.0	38.4	14.2	8.4	10.0

Typically, a bimodal distribution was encountered, generally with a peak around 5 microns, and another one for particles less than one micron. A typical distribution is shown in Figure 12.

3.4 POINT AND AREA HEAT EMISSION INVENTORY

This is a rather specialized inventory, since heat emissions in themselves are considered neither a "threat to public health" or "public welfare"--the criteria for the designation of pollutant. However, the cumulative heat emissions from large urban areas do create a "heat island" of warm air, thus introducing a meso-meteorological disturbance. Since meteorological conditions are of overriding importance to air pollution, an understanding of the magnitude and behavior of heat emissions is of considerable importance to air pollution meteorology.

Heat emissions to the atmosphere originate, directly or indirectly, from the combustion of fossil fuels (there are no nuclear plants in the St. Louis AQCR (19). With the exception of a small amount of energy radiated into space as light, and the energy carried out of the AQCR by cooling water (primarily the Mississippi River), all of the energy released by the combustion of fuels is sooner or later released to the atmosphere as heat, either at the point of production (the power stations) or where it is consumed.

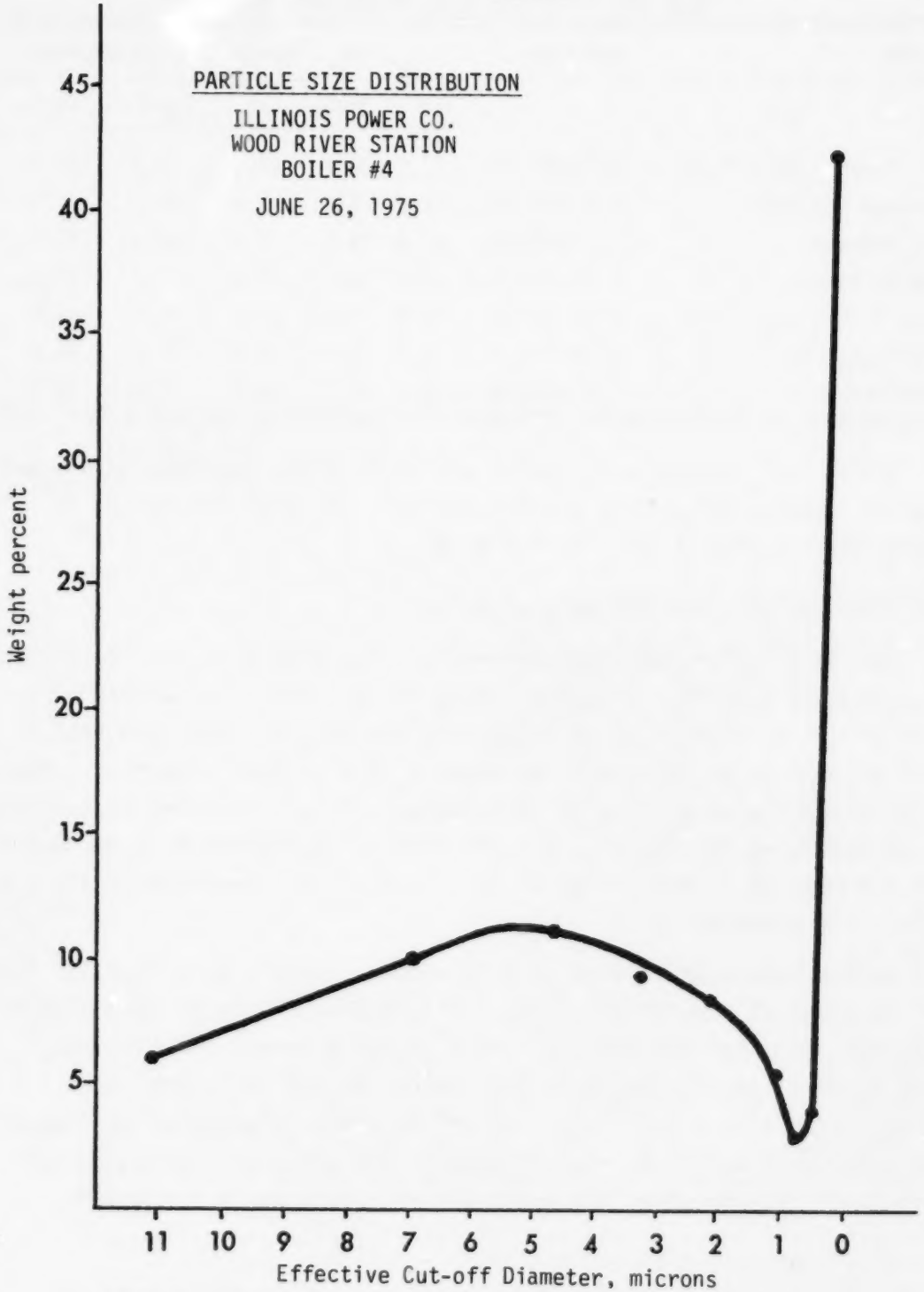


FIGURE 12. PARTICLE SIZE DISTRIBUTION - COAL FIRED BOILER

In the production of power, only a fraction of the energy released when the fuel is burned is emitted as heat emissions to the atmosphere. The remaining fraction of energy is converted to heat at the point of ultimate use. This is true whether the fuel is natural gas, electricity, gasoline or other sources.

Heat emission from point sources is only a small, albeit an important fraction of the total heat emissions. It is estimated that point source heat emissions account for about 11 percent of the total emissions in the AQCR. Point source emissions are, however, in the form of concentrated plumes, while other heat emissions are diffused. Thus, the meteorological dispersion behavior of these sources is likely to be quite different.

A first approximation of the amount of heat generated by the combustion of fuels in the St. Louis Air Quality Control Region (AQCR) can be obtained from fuel combustion figures of the 12 counties making up the AQCR. The breakdown is shown in Tables 22 and 23.

The data presented in these tables indicate that coal supplies 70 percent of the energy requirement of stationary point sources, but only 2.6 percent of the area sources. Natural gas supplies 20.5 percent of the requirement of point sources, but 69 percent of the area sources. The total amount of heat generated by conversion of fuel to energy by both stationary and mobile sources is of the order of 869×10^{12} Btu per year.

The amount of heat actually released to the atmosphere is, however, considerably less. There are several reasons for this. In a utility boiler, about 85 percent of the energy created by burning fuels is used in the production of steam (large utilities do a little better). Thus, about 15 percent of the heat content of the fuel escapes in the stack gases, which constitute the "point" heat emission sources. This amounts to about 61×10^{12} Btu. Less than half of the remaining 85 percent is converted to electricity, which eventually is released as an "area" source of heat. The other half--actually, about 55 percent--is carried off by cooling water, which in this area is the Mississippi River. Since this raises the river water temperature only minimally, virtually none of this heat is given off to the atmosphere. Additionally, about 15 percent of the power produced is used outside the AQCR. The

TABLE 22. POINT SOURCE FUEL CONSUMPTION

County	Coal (Bitum.) Tons	Residual Oil 10^3 gal	Distillate Oil 10^3 gal	Diesel Fuel 10^3 gal	Natural Gas 10^6 cu.ft.
(Illinois)					
Bond	---	---	742	60	---
Clinton	4,144	---	277	---	221
Madison	2,681,251	152,506	55,786	---	57,425
Monroe	---	---	---	---	---
Randolph	5,952,699	100	686	37	159
St. Clair	158,077	28,832	4,712	---	5,606
Washington	250	---	156	---	---
(Missouri)					
Franklin	5,673	3,401	3,525	---	41
Jefferson	18,760*	850	450	---	1,538
St. Charles	1,561,433	---	786	---	184
St. Louis (City)	205,266	1,076	191	---	5,032
St. Louis (County)	2,282,034	4,065	638	---	13,177
Total point source fuel consumption	12,869,587	190,830	67,949	97	83,383
Aver. Btu x 10^6/ SCC unit	22	150	140	140	1,000
Total heat content Btu x 10^{12}	283	29	9.5	---	83
All Point Sources		405 x 10^{12} Btu			

* Listed as anthracite

TABLE 23. AREA SOURCE FUEL CONSUMPTION

County	Coal (Bitum.) Tons	Residual Oil 10^3 gal	Distillate Oil 10^3 gal	LPG 10^3 gal	Natural Gas 10^6 cu.ft.	Electricity 10^6 KWH	Gasoline 10^3 gal	Diesel Fuel 10^3 gal
(Illinois)								
Bond	3,020	220	1,840	5,475	600	195 *	12,431	610
Clinton	5,160	320	2,220	8,805	1,360	211 *	13,309	1,280
Madison	61,020	3,250	25,210	39,630	18,370	1,684	111,833	21,254
Monroe	2,120	190	1,270	13,340	580	148 *	9,983	6,392
Randolph	8,540	420	3,100	13,505	1,370	245 *	16,054	6,620
St. Clair	56,410	3,320	22,640	44,920	16,480	1,145	116,286	16,285
Washington	3,530	160	1,200	9,785	680	127 *	10,408	652
(Missouri)								
Franklin	34,540	220	7,680	55,560	2,940	383	32,242	5,932
Jefferson	940	250	7,260	89,540	13,940	989	57,991	7,094
St. Charles	1,330	420	9,420	56,340	2,870	566	54,494	38,580
St. Louis (City)	330,500	10,000	78,000	16,620	60,000	4,597	217,680	23,970
St. Louis (County)	38,550	5,210	61,280	44,510	43,800	9,806	333,346	64,143
Total area source consumption	545,660	23,980	211,120	398,030	162,990	20,096	986,057	192,812
Aver. Btu x 10^6/ SCC unit	22	150	140	95	1,000	3,410	125	140
Total heat content Btu x 10^{12}	12	4	30	38	163	68	123	27
Total Btu all areas			464 x 10^{12}					

*Estimated

actual amount of heat released to the atmosphere in the St. Louis AQCR is estimated at 534×10^{12} Btu per year.

By contrast, essentially all of the heat released by area sources (space heating, cars and trucks, as well as a minor amount of process heating) is emitted as heat emissions to the atmosphere. The heat produced by the burning of fuel used for space heating is given off continuously to the atmosphere. One might expect that automobiles and electric motors convert a sizeable fraction of the energy they use into work, rather than waste-heat. Actually, only a time delay is involved. All kinetic energy stored, for example, in a moving automobile is converted to heat by friction and given up to the atmosphere, whether the friction is air resistance, rolling resistance or braking. Thus, the full amount of the heat content of fuels used in area sources plus a large fraction of the fuel used in point sources constitutes diffuse heat emission.

The determination of point source heat emissions involved the development of appropriate heat emission factors. Thus, in order to calculate the amount of heat emitted by a source, we need to know the amount of fuel consumed (or materials produced) per unit time, the heat value of the fuel, and the efficiency of the operation. These three factors were considered in deriving the heat emission factors for each source. These factors were keyed into the Standard Classification Code (SCC); thus, they will give values of the heat emission in units of 10^6 Btu per SCC unit. SCC units are: tons (for coal, etc.), 10^3 gal. (for oil, etc.) and 10^6 cu. ft. (for gases). The factors were designated by the code HEM and were entered into the RAPS file together with the appropriate source code.

Heat emission factors (HEM) cover a wide range of values. Those based on fuel consumption tend to average around .20, indicating a fuel conversion efficiency of 80 percent; their range is from .109 for the most efficient, modern power plants of the large utilities to .30 for older industrial installations. In-process fuel consumption is less efficient, with values generally of the order of .35, indicating 65 percent fuel utilization as, for example in a glass furnace. Even higher factors characterize municipal incinerators (.40). Finally, factors of 1.0 appear where fuel is wasted, such as in refinery flares. Some examples of typical heat emission factors are shown in Table 24.

TABLE 24. EXAMPLES OF POINT SOURCE HEAT EMISSION FACTORS (HEM)

*** PLANT	STKID	SCC	PLUTNT	EMFACT
MUNICIPAL POWER PLANT BREESE	01	10100208	HEM	.200
CARLYLE MUNICIPAL POWER	01	20100301	HEM	.200
ILLINOIS POWER CO. WOOD RIVER	01	10100501	HEM	.131
ILLINOIS POWER CO. STALLING	01	10100501	HEM	.200
	04	10100501	HEM	.200
UNION ELECTRIC CO. VENICE	01	10100501	HEM	.139
AMOCO OIL REFINERY	01	30600102	HEM	.150
	03	30600102	HEM	.150
	05	30600102	HEM	.150
	06	30600102	HEM	.150
	07	30600102	HEM	.200
	09	30600103	HEM	.250
	10	30600103	HEM	.250
	12	30600103	HEM	.250
	14	30600108	HEM	.250
	17	30600102	HEM	.250
	21	30600999	HEM	1.000
	22	30600999	HEM	.200
	23	30600999	HEM	1.000
	24	30600999	HEM	.200
CLARK OIL CO.	01	30600102	HEM	.250
	02	30600102	HEM	.250
	03	30600102	HEM	.250
	04	30600102	HEM	.250
	05	30600102	HEM	.250
	06	30600102	HEM	.250
	08	30600102	HEM	.250

Some heat emission factors are based on throughput or material produced. Such factors are no longer directly related to combustion efficiency and can, therefore, have any numerical value.

Area heat emission sources are assigned to a grid system developed for the St. Louis AQCR, which divides the study area into 1989 grid squares (20). These squares vary in size from 1 to 100 km^2, depending on population densities.

Area heat emission fall into three broad categories:

1) Heat emissions from the burning of fuel in stationary installation (e.g., space heating).

2) Heat emissions from the consumption of electric power, all of which eventually show up as heat.

3) Heat emissions from burning of fuel in mobile sources (e.g., cars, trucks, rail and airport operations).

Residential heating in the AQCR accounts for about 30 percent of the area heat emissions, or about 140 x 10^{12} Btu per year. As shown in Table 25, natural gas accounts for the bulk of it (87 x 10^{12} Btu), followed by LPG, oil, coal and wood. Hourly fuel consumption and, consequently, heat emissions were obtained using a regression equation based on actual hourly fuel consumption records for St. Louis. The equation takes into consideration ambient temperature and wind speed.

Commercial heating was estimated to produce about 56.4 x 10^{12} Btu per year. It was distributed spatially according to estimated land use per grid square and temporally using the same technique as residential heating.

Industrial area heat emissions, amounting to about 49 x 10^{12} Btu per year, were calculated by assigning an Area Heat Emission Factor (AHF) to each industrial source. This factor depends on the manner in which process heat is handled at each plant, that is, whether cooling water is used, how it is recirculated, etc.

The consumption of electric power accounts for 68 x 10^{12} Btu per year, second only to the heat released by the burning of gas. About 35 percent of the power consumption is residential, 10 percent commercial, 55 percent industrial. Heat emissions from residential usage were assigned to grid

squares based on the number of housing units and an average consumption of 8333 kwh per unit per year. Commercial power usage was based on land use data. The remainder was assigned to industrial usage to those grid squares containing industrial plants. Hourly values were calculated from seasonally adjusted power consumption data.

Heat emissions from mobile sources account for a large percentage of the total heat emissions. They were estimated at 150×10^{12} Btu per year, almost 30 percent of the total emissions. The basis for their distribution is "Vehicle-Kilometer-Traveled" (VKT) per grid square. This number is transformed into heat emissions per grid square using averaged fuel consumption figures of 21 km per gallon for light-duty vehicles, 9.7 km per gallon for heavy-duty vehicles.

Off-highway mobile sources, airports, railroads and vessels all contribute minor amounts to the heat emission in the AQCR and were also included. A summary of heat emissions is shown in Table 25. The heat emission software provides an hour-by-hour output on a grid square basis, including a stack-by-stack listing of point sources.

TABLE 25. SUMMARY OF ANNUAL HEAT EMISSIONS IN AQCR 70, 10^{12} BTU

	Coal	Res. Oil	Dist. Oil	Nat. Gas	Electricity	Gasoline	Diesel Fuel	LPG	Totals
Point Sources	42	4	3	12	--	--	--	--	61
Stationary Area Sources									
Residential	2	--	13	87	24	--	--	38	
Commercial	2	--	11	44	7	--	--	--	
Industrial	8	4	6	31	37	--	--	--	
TOTAL									314
Mobile Sources									
Highway Vehicles	--	--	--	--	--	115	8	--	
Off-Highway Vehicles	--	--	--	--	--	7	14	--	
Airport	--	--	--	--	--	2	--	--	
Railroads	--	--	--	--	--	--	9	--	
Vessels	--	--	--	--	--	--	5	--	
TOTAL									160
GRAND TOTAL	54	8	33	174	68	124	36	38	535

4.0 AREA SOURCE EMISSION INVENTORIES

The term "area sources" encompasses emissions from a large number of point sources, which are individually either too small to be of consequence (for example, domestic heating units), or difficult to measure under actual operating conditions, such as automobiles. While such sources may be individually negligible, their large number and accumulative total emissions make them significant contributors to air pollution.

4.1 THE RAPS GRID SYSTEM

Customarily, in inventories to be used in simulation models, area sources are distributed over a network of grids. For the purposes of RAPS, a grid network was designed (20), based on the following design parameters:

1) The grid network is formed by squares, though not necessarily of the same size.

2) The length of the side of each square needs to be an integer; e.g., 1, 2, 3, 5 or 10 km.

3) The network is based on the Universal Transverse Mercator coordinate system (Zone 15).

4) Each square should have approximately the same population, but cannot be smaller than 1 km^2.

The eastern portions of the AQCR is in UTM Zone 16. To simplify modeling requirements, UTM Zone 15 was extended eastward to include the whole AQCR, and all grid square locations are based on Zone 15 coordinates. A grid square is defined by its size and the location its SW corner on the UTM coordinate system.

The system is shown in Figure 13.

4.2 RESIDENTIAL AND COMMERCIAL EMISSION INVENTORY

This inventory deals with several major categories of area emissions:

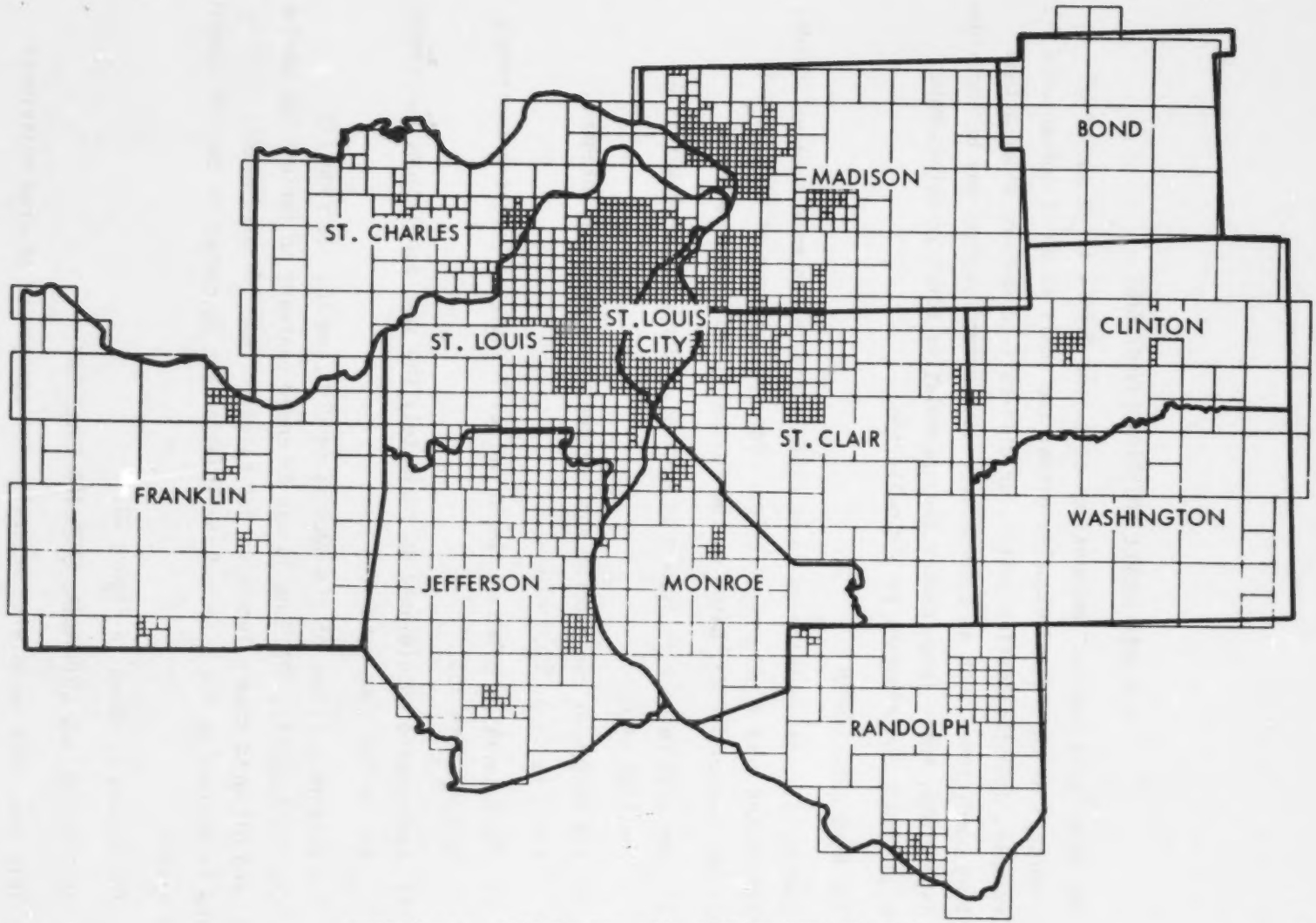


FIGURE 13. EXAMPLE OF RAPS GRID SYSTEM OVERLAY

residential and commercial fuel use for space heating, evaporative hydrocarbon losses from dry cleaning, surface coating and gasoline marketing, solid waste disposal and structural fires. Emissions from each of these categories were apportioned to the 1989 grid squares and given an appropriate temporal distribution (21).

4.2.1 Space Heating

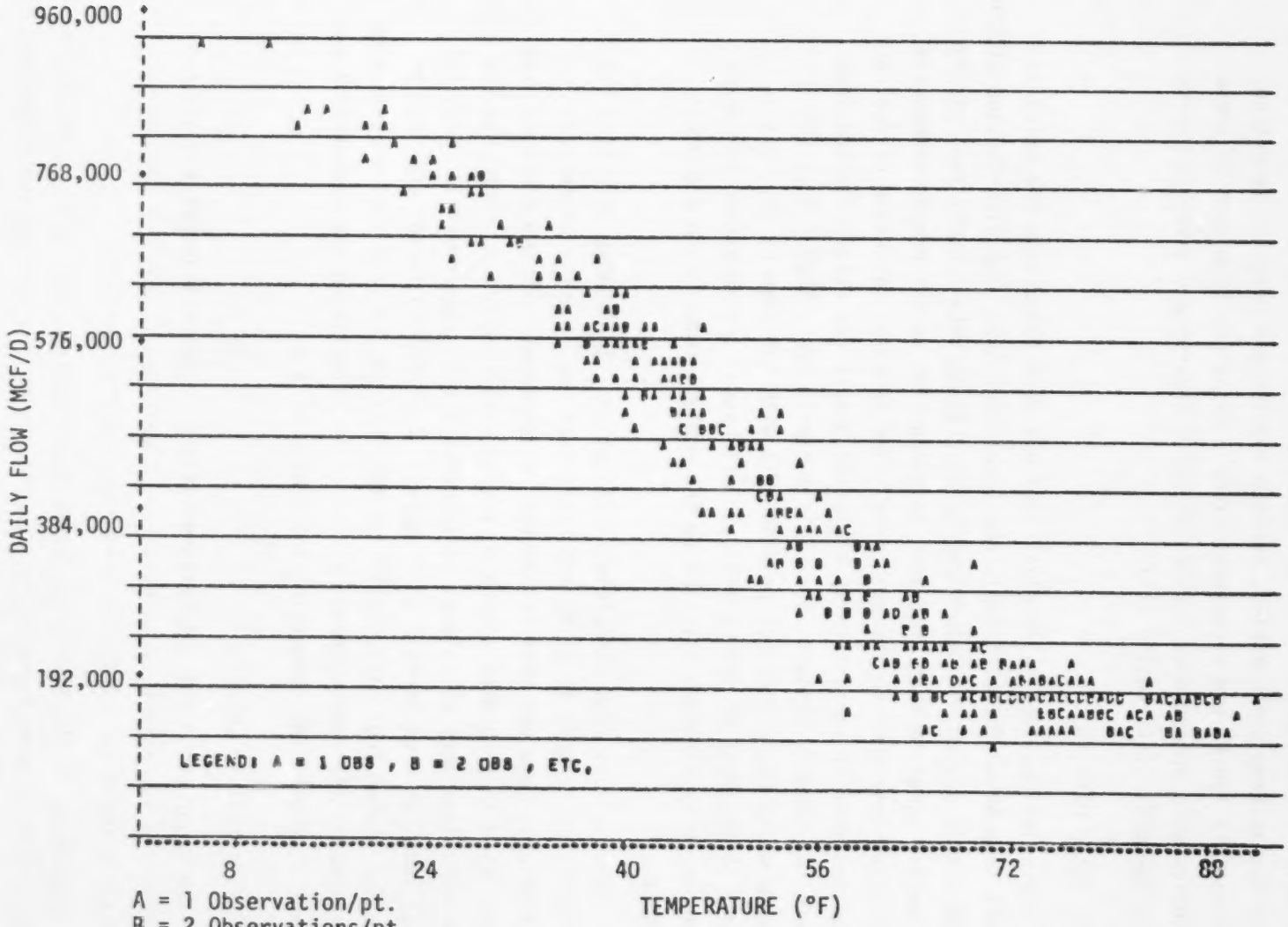
The emissions from residential fuel use were based upon the emission factors from AP-42 for each fuel, and local fuel use. The distribution within the RAPS grid system was determined by allocating total county fuel use for residential usage to each grid area in proportion to the number of housing units using that fuel in the grid area. The temporal variation of fuel use was established by statistically analyzing hourly gas usage obtained from Laclede Gas Company (Figure 14). This analysis identified a base component of usage which has a distinct relationship with the time of day, but is largely independent of meteorological influence. The remaining component was shown to be strongly affected by the ambient temperature and wind velocity.

The emissions from commercial/institutional fuel usage were also based upon emission factors in AP-42 and local fuel use. County commercial/institutional land use area was located using local land use planning maps and assigned to each grid square as a grid area percentage. Fuel use and hence emissions were calculated in accordance with the commercial/institutional land use area in each grid square. A corrected factor was used to allow for uneven fuel distribution in the vicinity of main fuel distribution (gas) lines. The same temporal distribution established for residential fuel use was also used for commercial/institutional use.

4.2.2 Evaporative Emissions

The major components of residential and commercial-institutional area sources of evaporated hydrocarbons were identified as surface coating (primarily painting), gasoline handling, and dry cleaning.

According to the St. Louis County dry cleaning plant survey, 89 percent of dry cleaning establishments use perchloroethylene solvent and 63 percent of



A = 1 Observation/pt.
B = 2 Observations/pt.
C = 3 Observations/pt.

FIGURE 14. DAILY GAS FLOW VS. AVERAGE DAILY TEMPERATURE

all clothes are cleaned with this material. Based on the St. Louis County data, .53 pounds of hydrocarbons from this type of source are emitted per capita per year. It was assumed that this per capita figure was applicable for the entire AQCR. The emissions occur during normal working hours (8 AM to 5 PM, Monday through Friday) and were temporally allocated to this time period. The emissions were spatially distributed according to the commercial land use in each grid square.

Paint consumption was estimated from regional sales figures at 2.3 gallons per capita for Illinois, 2.7 gallons for Missouri. An averaged value of 1.14 pounds of volatile hydrocarbons per gallon of paint was used. Evaporation of the hydrocarbons was allocated to each grid on a population basis, with a temporal distribution corresponding to an 8 AM to 5 PM, five day work week. No seasonal adjustments were made.

Evaporative losses of hydrocarbons at service stations occur from filling losses of underground and automobile tanks and from spillage. County emission figures were derived from state gasoline sale totals, assuming gravity drop splash filling without control equipment. The losses were spatially distributed according to the amount of commercial land use in each grid square. Temporal distribution was based on the diurnal traffic cycle for St. Louis, using separate values for weekdays, Saturdays and Sundays. A monthly correction factor was used to allow for the differences in summer and winter gasoline sales.

4.2.3 Structural Fires and Solid Waste Disposal

Emissions from structural fires were difficult to quantify; however, average data were used and total estimated county emissions were allocated to grid areas based on the number of homes in the grid. Emissions were based on an average of 7 tons of combustible material burned in each fire and emission factors for open burnings for municipal solid waste. A uniform temporal distribution was used.

Emissions from the disposal of solid wastes are largely restricted to commercial-institutional enterprises and large incinerators because of the restrictive air pollution regulations. Thus, the county emissions were allocated to grid areas in proportion to the commercial-institutional land

use in each grid square. Emissions were given a temporal distribution on an 8 AM - 5 PM, five day work week. A summary of emissions from this category is shown in Table 26.

4.3 HIGHWAY VEHICLE EMISSION INVENTORY

4.3.1 Line Source Definition

This inventory was developed in two stages. The first stage was developed to document the criteria for determining the major freeway and arterial roadways to be considered emission line sources in a metropolitan area (22). In developing these criteria for the St. Louis Air Quality Control Region (AQCR) the 1975 traffic data maps were used. The data collection effort focused primarily on areas designated as urban or in the process of urbanizing. Data pertaining to traffic volume, vehicle mix, and average vehicle speed, were collected for the roadways in the St. Louis AQCR. Figure 15 shows the road network in St. Louis City and County.

All roadways were plotted as links with UTM coordinates and RAPS Gridding System grid square numbers, with appropriate traffic data (such as average daily total traffic) being assigned to each link. A complete data base for freeways, principal arterials, and minor arterials was thus established, along with an elaborate software package for retrieval of these data.

4.3.2 Highway Vehicle Line and Area Source Emissions

The second stage developed the detailed procedure for obtaining emissions from mobile sources for each grid square for both line and area sources (23). The East-West Gateway Coordinating Council under sponsorship of the U.S. Department of Transportation performed an extensive study in the St. Louis area, in which driving characteristics on several hundred miles of freeways and major arterials were measured. Using this speed versus time data a computer program was developed which differentiates 58 different driving patterns (29 peak hour and 29 off-peak hour patterns) depending on the road classification, average daily traffic, and volume-to-capacity ratio. Using these driving patterns as input to the EPA developed modal emission program, emissions for both peak and off-peak hours were calculated. The hourly emissions are then totaled for total daily emissions. Factors considered

TABLE 26. SUMMARY OF STATIONARY RESIDENTIAL AND COMMERCIAL EMISSIONS

RAPS AREA SOURCE EMISSIONS

COUNTY SUMMARY

AQCR 70

TONS/YR

SOURCE	PART	SOX	NOX	HC	CO
STA RES & COMM					
RESID FUEL OIL	546.5	1572.6	655.1	163.8	273.4
RESID NATURAL GAS	432.0	25.2	3453.4	345.1	863.0
RESID LPG	385.9	1.7	1622.7	162.8	405.9
RESID COAL	2079.1	9873.3	311.8	2079.1	9354.6
COMM FUEL OIL	894.8	6676.1	3000.0	149.3	198.8
COMM NATURAL GAS	218.1	12.0	2612.4	173.7	435.3
COMM LPG	.0	.0	.0	.0	.0
COMM COAL	1608.4	5457.1	528.5	114.8	413.6
EVAP HC-SRFC COATING	.0	.0	.0	3806.7	.0
EVAP HC-AUTO. TANKS	.0	.0	.0	13649.8	.0
EVAP HC-DRY CLEANING	.0	.0	.0	644.9	.0
STRUCTURAL FIRES	305.8	17.8	114.6	573.5	1625.3
SOLID WASTE DISPOSAL	127.0	13.9	23.6	102.4	206.0

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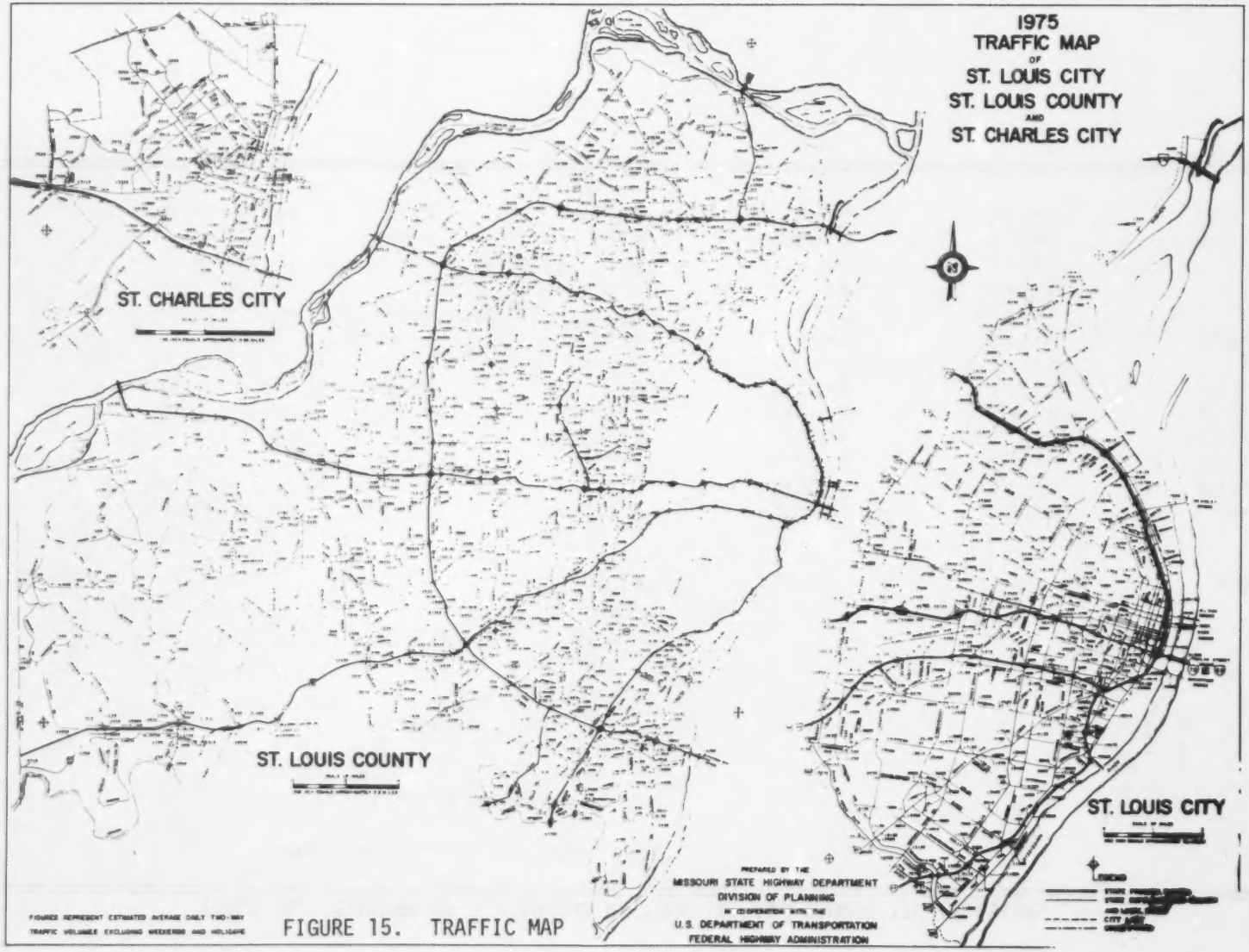

FIGURE 15. TRAFFIC MAP

include vehicle age and mixture, gasoline and diesel engined traffic, hourly distribution of traffic, and hot and cold starts. The effective date of the modal emission model is July 1975. In addition to evaporative hydrocarbon losses, the variation of emissions due to weekend vs. weekday traffic volumes were calculated. Re-entrained dust from paved roads (assuming an emission factor of 5 grams per vehicle mile traveled) was also calculated, and was kept as a separate category (i.e., it was not combined with exhaust particulate emissions). In addition to line source emissions, the program computes area source vehicle emission. Since it had been shown that traffic on feeder routes was proportional to line source traffic, the sources were expressed as a fraction of line source traffic. The fraction appropriate for St. Louis was determined to be 18%, which differs significantly from an average national value of 40%. Table 27 shows a sample printout of two line source links, Table 28 emissions from mobile sources in a grid square.

Emissions data for criteria pollutants from highway vehicles are available for any hour and grid square. The same data are also available for each link.

4.4 RIVER TOWBOAT EMISSIONS

The emissions were estimated for river towboats operating on the waterways within the RAPS region. This area includes the Mississippi River, from Mile 100 below St. Louis to Mile 235 above St. Louis; and the Missouri River from the confluence of the Mississippi River to near Mile 95. River miles given here are based on Corps of Engineers river distance measured above the mouth of the Ohio River. The Gateway Arch in St. Louis is located near Mile 180. This area is shown in Figure 16.

The emissions calculated include: carbon monoxide (CO), oxides of nitrogen (NO_X), total hydrocarbon (THC), oxides of sulfur (SO_X), and Particulates (Part). The study methodology was limited to air pollutants emitted from river towboat diesel engines. Emissions originating from ship electrical-service generating units, cargo, loading and unloading activities, and fueling and maintenance operations were not included (24).

The methodology consists of estimating river traffic and propulsion engine characteristics from limited statistical information on river traffic

TABLE 27. EXAMPLE OF HOURLY LINE SOURCE EMISSIONS (grams)

LINK 3081 GRID 1736 COUNTY 147920 DATE SPAN 75001-75001
FUNCTIONAL CLASS 2 ENDPOINTS (796.7,4235.0)(796.3,4245.0) LENGTH 10.01 KM

PART	SOX	NOX	HC	CO	FUGDST
69	23	517	890	8365	666
46	15	346	595	5590	445
21	7	161	278	2609	208
12	4	87	150	1408	112
10	3	72	123	1159	92
26	9	197	339	3188	254
109	36	825	1419	13334	1061
230	76	1737	2989	28075	2235
208	69	1568	2698	25342	2017
173	57	1304	2244	21077	1678
182	60	1371	2358	22154	1763
200	66	1511	2601	24431	1945
220	73	1657	2852	26791	2132
208	69	1570	2702	25384	2020
218	72	1642	2826	26543	2113
262	87	1975	3399	31926	2541
309	102	2329	4007	37641	2996
310	102	2336	4020	37765	3006
253	84	1911	3289	30891	2459
241	80	1821	3134	29442	2343
199	66	1504	2588	24307	1935
171	56	1289	2217	20829	1658
128	42	966	1666	15653	1246
92	30	694	1195	11222	893

LINK 3082 GRID 1737 COUNTY 147920 DATE SPAN 75001-75001
FUNCTIONAL CLASS 2 ENDPOINTS (790.0,4251.2)(796.0,4251.6) LENGTH 6.01 KM

PART	SOX	NOX	HC	CO	FUGDST
73	26	568	949	8839	698
49	17	379	634	5907	466
23	8	177	296	2757	218
12	4	96	160	1488	117
10	4	79	132	1225	97
28	10	216	362	3369	266
117	41	905	1513	14090	1112
247	87	1905	3185	29668	2342
223	78	1719	2875	26780	2114
185	65	1430	2391	22273	1758
195	68	1503	2513	23411	1848
215	75	1658	2771	25817	2038
235	83	1818	3039	28312	2235
223	78	1722	2879	26824	2118
233	82	1801	3011	28049	2215
280	99	2166	3622	33738	2664
331	116	2554	4270	39776	3140
332	117	2562	4284	39908	3151
271	95	2096	3504	32644	2577
259	91	1998	3340	31112	2456
214	75	1649	2757	25686	2028
183	64	1413	2363	22011	1738
137	48	1062	1776	16541	1306
99	35	761	1273	11859	936

TABLE 28. EXAMPLE OF HOURLY AREA SOURCE EMISSIONS (kg/hour)

Grid 602 County 264300 Date October 1, 1976

Hour	Part.	SO_2	NO_x	HC	CO	Fugitive Dust
0	.025	.011	.205	.434	4.212	.219
1	.012	.005	.096	.203	1.966	.102
2	.006	.003	.052	.109	1.061	.055
3	.005	.002	.043	.090	.874	.046
4	.014	.006	.117	.246	2.403	.125
5	.059	.025	.490	1.036	10.048	.524
6	.121	.053	1.032	2.180	21.156	1.102
7	.112	.048	.931	1.968	19.096	.995
8	.093	.040	.775	1.637	15.883	.828
9	.098	.042	.814	1.721	16.694	.870
10	.108	.046	.898	1.897	18.410	.959
11	.118	.051	.985	2.081	20.189	1.052
12	.112	.048	.933	1.971	19.128	.997
13	.117	.050	.975	2.061	20.001	1.042
14	.141	.061	1.173	2.480	24.058	1.254
15	.166	.071	1.383	2.923	28.364	1.478
16	.167	.072	1.388	2.933	28.458	1.483
17	.137	.059	1.135	2.399	23.278	1.213
18	.130	.056	1.082	2.287	22.186	1.156
19	.107	.046	.893	1.888	18.316	.954
20	.093	.039	.765	1.618	15.695	.818
21	.069	.030	.575	1.216	11.795	.615
22	.050	.021	.412	.872	8.456	.441
23	.037	.016	.307	.650	6.303	.328

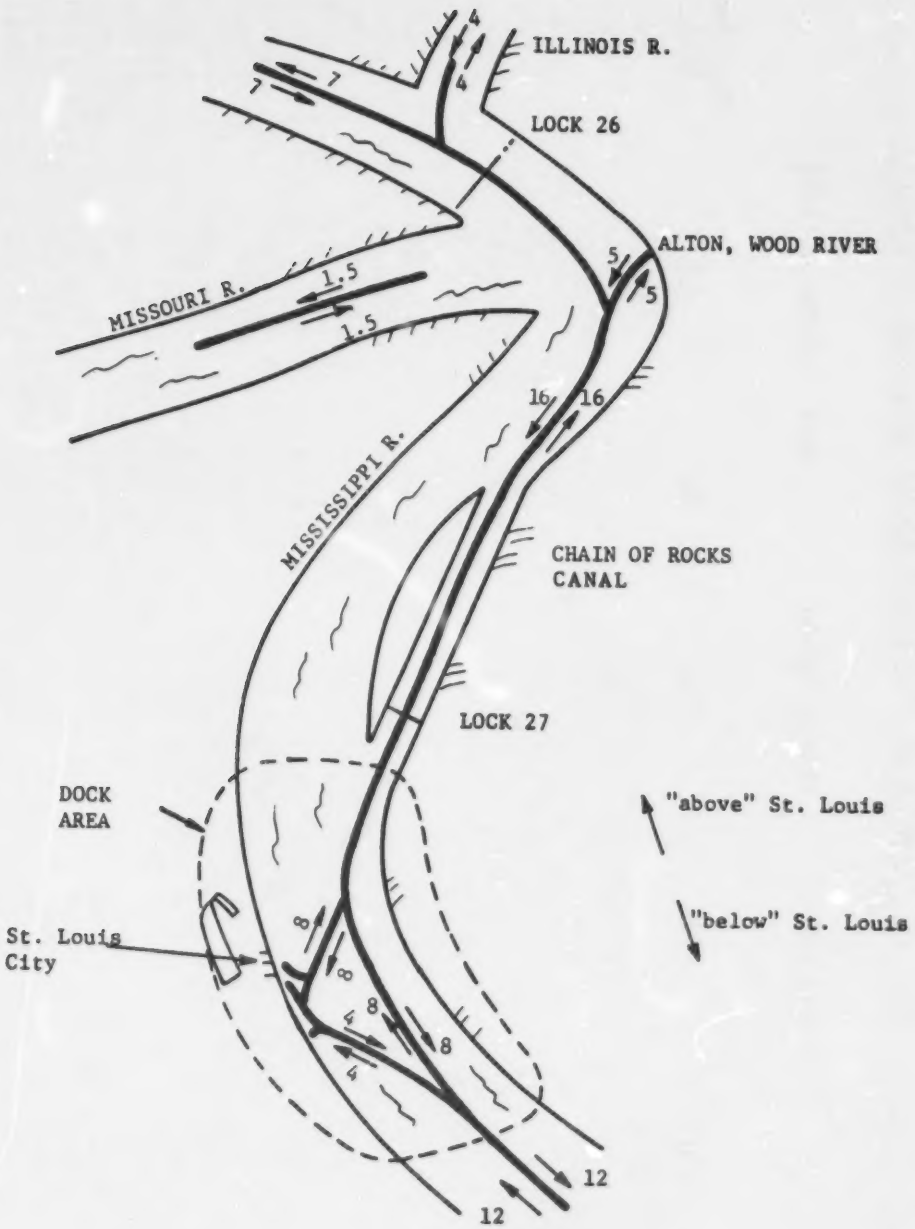

FIGURE 16. ST. LOUIS AREA RIVER VESSEL TRAFFIC
(NUMBERS REFER TO VESSELS PER DAY)

and from observations by Coast Guard and Army Corps of Engineers personnel familiar with river vessel operations. The traffic volumes and engine types were then used to calculate emissions, based on measurements of emission factors for similar diesel engines used on Coast Guard vessels and rail locomotives. No emission testing of towboats was undertaken during the RAPS program.

Emission estimates were made from the averages of daily river traffic volume and towboat engine characteristics. The volume of traffic was low and the range of vessel characteristics large, so that an estimate of hourly emission rates was not practical. The traffic data acquired displayed little variation on a daily or monthly basis, therefore, no temporal pattern was applied to the emissions. No error estimate or sensitivity analysis was made, as a greater level of effort would be required to establish the distribution and accuracy of all the variables. The estimation is believed to be sufficiently accurate to determine the relative contribution of towboats to St. Louis air pollution and to serve as input data for the urban atmospheric dispersion models. Air pollutants emitted by river vessels were calculated as:

$$\text{Emissions} = \text{Horsepower-hours} \times \text{Emission Factors}$$

Horsepower-hours per grid equal (No. of towboats per day) x (average HP x average throttle position) x within grid travel distance/average speed).

From other information sources, it is known that ice on the Missouri River and on the upper reaches of the Mississippi curtail vessel movements during the winter months. Likewise, periods of high water reduce towboat operations. The Mississippi River throughout the region is normally open to river traffic all year long. Stoppages in towboat operations due to weather are infrequent and thus no emission reduction is assumed for this area. The Missouri River is normally closed to navigation from the beginning of December to the first of March. (The actual dates are a function of the weather conditions.) Therefore, vessel emissions are considered to be zero for the Missouri River from 1 December to 1 March each year. The annual emission results were:

TOWBOAT EMISSIONS:	Particulate	SO_2	NO_X	HC	CO
TONS/YEAR	198	462	3297	939	2101

These emissions were distributed over only the grid squares containing river vessel activity. The apportioning factor which was used to distribute the emissions was linear length over which the vessels traversed within the grid. An example of daily river vessel emissions per grid is shown in Table 29.

4.5 EMISSIONS FROM AIRPORT OPERATIONS

A methodology was developed to detail emissions resulting from airport operations for civilian, municipal, and military airports in the St. Louis AQCR (25). The sources involved include aircraft operations and engine maintenance testing, ground support vehicles, and fuel storage and handling. For these sources, the emission rate, emission location, and emission duration need to be described.

To estimate hourly emissions from aircraft flight operations five parameters must be known:

- Temporal activity patterns
- Spatial activity patterns
- Percent volume distribution of aircraft types
- Time spend in the different operating modes
- Emission factors.

For flight operations, the following elements were considered:

TABLE 30. AIRCRAFT OPERATING MODES

Mode	Engine operating time included in mode
Taxi	Transit times between ramp and apron, apron and runway and time required for turning and alignment between taxiway and runway.
Idle	Push back from gate; waiting for signal to begin taxiing; waiting at taxiway intersections; runway queuing; gate queuing.
Landing	Touchdown to beginning of taxi in taxiway.
Takeoff	After alignment with runway to lift-off.
Approach	3000 ft. altitude to touchdown.
Climb-out	Lift-off to 3000 ft. altitude.

TABLE 29. EXAMPLE OF RIVER VESSEL EMISSIONS PER GRID (kg x 10^{-1}/day)

GRID	PART	SO_X	NO_X	HC	CO
197	30.0	70.0	510.8	100.2	195.0
242	148.1	345.7	2522.4	495.0	963.1
286	2.3	5.4	39.7	8.0	15.3
287	2.5	6.0	43.5	8.8	16.7
288	7.0	16.4	118.8	24.1	45.8
308	7.7	18.0	130.7	26.5	50.3
309	8.6	20.2	146.4	29.7	56.4
355	145.6	339.7	2478.6	486.4	946.4
392	14.0	32.8	237.4	48.2	91.5
394	99.3	231.8	1691.6	331.9	645.9
503	31.2	72.8	531.6	104.3	203.0
527	231.0	539.1	3933.2	771.9	1501.8
528	176.8	412.6	3010.2	590.7	1149.4
529	119.8	279.7	2040.7	400.5	779.2
568	6.8	15.8	114.7	23.3	44.2
569	15.2	35.6	257.2	52.3	99.2
699	153.4	357.9	2611.5	512.5	997.1
737	9.4	21.9	158.2	32.1	61.0
738	6.5	15.3	110.8	22.5	42.7
739	138.5	323.2	2358.2	462.8	900.4
813	58.3	136.1	993.0	194.8	379.1
814	30.7	71.8	523.8	102.7	200.0
815	8.5	19.8	170.3	54.4	99.4
847	29.3	68.2	536.9	136.9	256.5
848	35.2	81.9	623.8	143.4	272.5
849	8.0	18.6	155.0	46.2	85.0
877	160.7	375.1	2736.8	537.1	1045.0
914	4.7	11.1	73.6	20.0	31.0
915	8.0	18.6	136.1	26.7	52.0
916	47.1	110.0	802.8	157.5	306.5
917	23.5	55.0	401.4	78.7	153.2
923	7.8	18.2	132.9	26.0	50.7
924	36.1	84.1	639.4	146.5	278.5
925	11.0	25.7	187.6	36.7	71.6
955	41.2	95.8	776.7	215.6	399.7
956	3.2	7.5	54.7	10.7	20.9
977	28.6	66.8	487.4	95.6	186.1
998	45.2	105.0	824.9	209.2	392.3
999	3.1	7.1	91.2	49.5	86.4

Ground Support emissions used at municipal airports result from the service vehicles shown in Table 31.

TABLE 31. SERVICE VEHICLES USED AT A MUNICIPAL AIRPORT

Vehicle
1. Tractor
2. Belt loader
3. Container loader
4. Cabin service
5. Lavatory truck
6. Water truck
7. Food truck
8. Fuel truck
9. Tow tractor
10. Conditioner
11. Airstart
Transporting engine
Diesel power unit
12. Ground power unit
Transporting engine
Gasoline power unit
Diesel power unit
13. Transporter

At civilian and military airports, service vehicles are primarily fueling trucks.

The information is processed by a computer program. The program output is listed directly in emissions of pollutant per grid square per hour. It utilizes the data on aircraft operations mentioned above and modal emission factors summarized in AP-42. The methodology also takes into consideration the wind direction in order to determine active runway, types of aircraft and services at each of the 15 general aviation airports, Lambert Municipal airport and Scott Air Force Base. Table 32 shows a printout of hourly

TABLE 32. EXAMPLE OF HOURLY AIRPORT EMISSIONS

RAPS AREA SOURCE REPORT

HOURLY AIRPORT EMISSIONS IN GRAMS

GRID 523 1/01/75

HR	PART	SOX	NOX	HC	CO
1	.65	.47	6.23	15.20	25.97
2	.46	.31	3.84	13.25	21.90
3	.44	.24	2.68	13.31	21.75
4	.11	.11	1.57	3.40	5.64
5	.16	.18	2.42	5.48	8.93
6	.09	.09	1.04	5.52	8.75
7	.52	.49	6.59	17.84	29.11
8	1.32	1.14	14.66	48.28	78.36
9	2.29	1.95	25.30	86.47	129.20
10	2.75	2.42	32.23	97.68	146.80
11	2.83	2.19	27.76	100.36	150.66
12	3.01	2.44	32.19	98.61	149.38
13	2.79	2.33	30.59	104.48	145.24
14	3.02	2.63	35.21	110.71	154.29
15	3.16	2.10	26.36	103.35	145.21
16	2.93	2.26	30.01	85.21	131.04
17	2.97	2.52	33.27	103.82	156.26
18	2.88	2.39	31.05	103.18	154.86
19	2.44	2.10	27.74	85.69	128.90
20	2.07	1.77	22.97	77.55	115.92
21	1.91	1.64	21.70	61.94	101.63
22	1.06	1.15	15.98	40.04	63.41
23	.95	1.06	14.70	37.85	59.95
24	.40	.39	5.10	17.33	27.44

HOURLY AIRPORT EMISSIONS IN GRAMS

GRID 523 1/02/75

HR	PART	SOX	NOX	HC	CO
1	.41	.47	6.06	15.91	26.86
2	.29	.31	3.76	13.74	22.64
3	.26	.24	2.62	13.81	22.59
4	.07	.09	.89	3.55	5.76
5	.11	.14	1.43	5.72	9.22
6	.09	.10	.93	5.73	9.13
7	.33	.40	4.11	18.59	29.96
8	.85	1.01	10.01	50.25	80.83
9	1.41	1.68	16.85	89.76	132.91
10	1.64	2.00	20.30	101.49	150.57
11	1.63	1.91	18.95	104.11	154.53
12	1.67	2.01	20.32	102.41	152.47
13	1.61	1.94	19.59	108.24	148.72
14	1.74	2.13	21.74	114.27	157.79
15	1.57	1.81	17.90	106.92	147.74
16	1.49	1.79	18.27	88.52	132.56
17	1.74	2.10	21.22	107.83	160.11
18	1.70	2.03	20.38	107.12	158.90
19	1.44	1.74	17.62	89.01	132.13
20	1.27	1.52	15.21	80.51	119.23
21	1.13	1.37	13.83	64.51	104.21
22	.81	.98	10.24	41.74	71.17
23	.74	.90	9.41	39.45	66.13
24	.31	.37	3.67	18.01	29.75

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emissions for a 1 km^2 grid square located near Lambert field. Table 33 shows examples of annual emissions for a number of affected grid squares.

4.6 EMISSIONS FROM RAIL OPERATIONS

A methodology was developed for calculating and reporting fuel use and air pollutant emissions from railroad locomotive activity (26). The procedure utilizes automated techniques to report rail activity on the RAPS variable-sized grid system.

Separate methodologies were developed for the two major types of rail activity--road or line-haul operation and activity within switch yards. The methodology for road locomotives utilizes a line source concept and node points within the study area. The methodology for switch yard operation utilizes an area source concept. Both methodologies use as a basic unit locomotive horsepower-hours and were programmed to provide an analysis of fuel use and emissions for five criteria pollutants on a grid-by-grid basis as well as for the entire study area.

Locomotive diesel engine fuel use and emissions vary considerably among the various engine types, sizes, and modes of operation. Thus, it was necessary to categorize each locomotive of the three principal manufacturers into one of five engine categories based on horsepower rating and maker. Load factors, representing the average portion of available horsepower typically used in performing an activity, were derived from previous studies.

The types of locomotives in use in the St. Louis AQCR are shown in Table 34.

TABLE 34. CATEGORIZATION OF LOCOMOTIVE TYPES IN ST. LOUIS RAIL ACTIVITY INVENTORY

Maker	Horsepower Range	Engine Type
ALCO (Montreal Locomotive)	1,000	4-Stroke Switch
ALCO (Montreal Locomotive)	1,600-2,000	4-Stroke Road
General Electric	600	4-Stroke Switch
General Electric	2,500-3,300	4-Stroke Road
General Motors (EMD)	600-1,500	2-Stroke Supercharged Switch
General Motors (EMD)	1,600-2,300-2,500	2-Stroke Supercharged Road
General Motors (EMD)	2,400-2,750-3,600	2-Stroke Turbocharged Road

TABLE 33. EXAMPLE OF ANNUAL AIRPORT GRID EMISSIONS (grams)

GRID	CO	HC	NOX	SOX	PART
76	20337	1672	34	20	
241	47454	3992	80	48	
242	20337	1726	34	20	
389	8416	1119	37985	2774	1773
451	48681	4294	4926	517	2481
452	29800	8382	24590	1687	1099
467	11298	1114	19	11	
492	594381	445858	69951	8213	9437
493	158389	36649	42546	3376	4246
522	41128	1064	3620	326	506
523	718591	675061	123442	10298	8863
524	100966	10508	10054	1185	5347
559	19112	9391	11030	1002	588
560	48319	5093	19760	1300	1112
588	3859	501	12365	1003	681
589	3859	501	12365	1003	681
616	3859	501	12365	1003	681
653	3859	501	12365	1003	681
654	3859	501	12365	1003	681
683	3859	501	12365	1003	681
883	10683	904	18	11	
1401	3609	1815	7	3	
1402	38211	2907	70	39	
1403	4856	302	11	4	
1424	20245	1423	42	20	
1444	1022	23	4		
1620	109880	82936	11740	1112	4405
1621	36646	3282	4531	325	1470
1633	6034	642	10	6	
1637	65705	3760	8771	632	3004
1709	21090	1786	35	21	
1815	29176	2375	49	30	
2021	6333	782	7	6	
2024	4513	296	10	4	
2102	45194	3812	76	46	
2103	33177	2921	48	34	
2104	11551	787	25	11	
2125	2800	181	6	2	
2161	97921	8008	165	100	
2187	8416	1119	37985	2774	1773
2286	44867	3782	66	46	
2289	6754	574	9	7	
2292	24960	1675	55	25	
2293	59542	4909	93	61	
2297	8521	2133	19	8	
2388	41445	809	5464	383	1867

Application of this methodology in the St. Louis AQCR required an inventory of railroad activity (Figure 17). This inventory was supplied by the U.S. Department of Transportation, Transportation Systems Center, and included information on the routing, run time, and locomotive(s) for each train in operation on a typical day plus estimates of switch yard and transfer activity. Fuel use and emission factors were those presented in the Environmental Protection Agency's document, Compilation of Air Pollutant Emission Factors (AP-42). Emissions from only diesel locomotive operations were included in the inventory. The quantity of emissions from evaporation and spillage of fuel and volatile freights have thus not been evaluated.

Approximately 800 of the 1989 grids comprising the RAPS grid system contained railroad activity. Annual fuel use by locomotives was estimated at 70,000 thousand gallons and total AQCR rail pollutant emissions are as follows:

Pollutant	Emissions (tons/yr)
Particulates	876
Sulfur Oxides	2,000
Carbon Monoxide	4,350
Hydrocarbons	4,220
Nitrogen Oxides	11,930

Locomotive emission factors (measured as pounds of pollutant emitted per thousand gallons of fuel used) were derived based on the mix of engine types in St. Louis. There was no attempt to develop any daily or seasonal temporal activity pattern. Examples of emissions from rail operations apportioned to the appropriate grid squares, are shown in Table 35.

4.7 OFF-HIGHWAY MOBILE SOURCES EMISSIONS

Emissions from off-highway motorcycles, motor boats, lawn and garden equipment, construction, industrial and farm equipment were estimated by a variety of techniques (27 & 28). Data for these categories are scarce even on the national level. The methodologies involved a breakdown of national or state data, sales figures, registrations, etc. to county and ultimately grid square level on the most appropriate basis available. This involved population

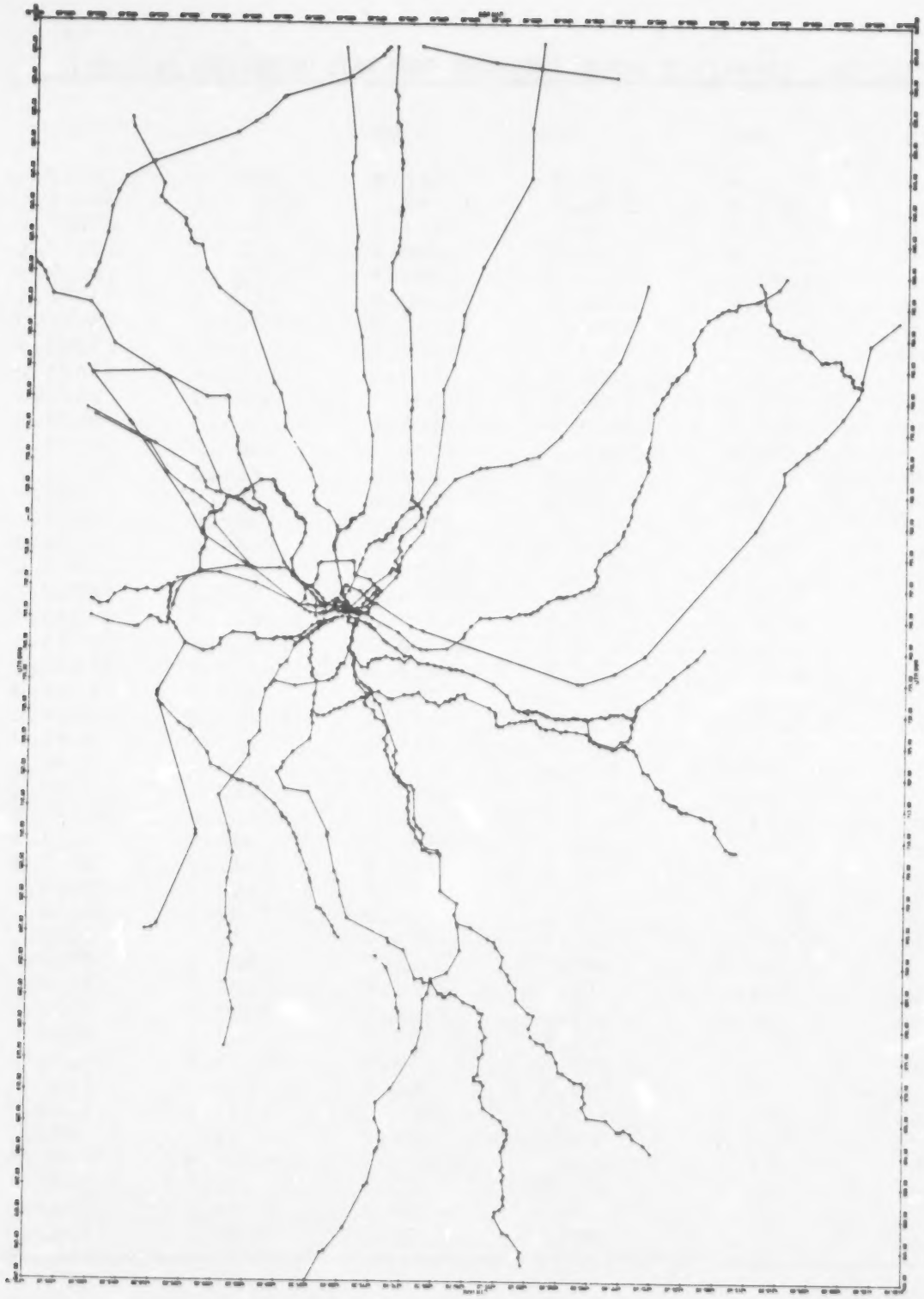

FIGURE 17. ST. LOUIS AQCR RAIL NETWORK

TABLE 35. EXAMPLES OF ANNUAL EMISSIONS FROM RAIL OPERATIONS (kg/year)

GRID	PART	SOX	NOX	HC	CO
2	1108.7	2527.9	6556.5	2391.9	14067.6
4	2423.4	5525.5	11759.2	10845.6	36616.1
8	1375.5	3136.1	6674.3	6155.7	20782.5
9	1204.0	2745.2	5842.3	5388.4	18192.1
12	1368.2	3119.5	8090.9	2951.6	17359.8
14	2204.7	5026.9	10698.0	9866.9	33311.9
15	2322.4	5295.1	11268.8	10393.3	35089.0
19	1968.3	4487.8	9308.2	7454.6	28252.9
20	916.1	2088.8	5417.5	1976.4	11624.0
21	596.2	1359.5	3526.0	1286.3	7565.5
22	4555.2	10385.9	22102.9	20385.6	68824.5
27	1342.8	3061.7	6350.4	5085.8	19275.2
28	122.5	279.3	579.4	464.0	1758.6
51	37.8	86.3	183.8	169.5	572.4
52	444.1	1012.6	2155.1	1987.6	6710.6
57	687.9	1568.4	4067.8	1484.0	8728.0
59	2277.2	5192.1	11049.7	10191.2	34407.0
61	1263.2	2880.2	3544.4	7967.2	16522.6
66	2384.8	5437.3	11277.6	9031.8	34230.4
67	5043.6	11499.6	30770.7	17869.4	79593.6
68	2093.8	4773.8	10159.5	9370.2	31635.0
69	149.2	340.2	955.0	167.1	1969.8
73	3689.8	8412.8	22214.7	14053.8	59559.2
74	158.5	361.4	1014.4	177.5	2092.3
75	192.8	439.6	1234.1	215.9	2545.5
77	795.8	1814.6	2233.0	5019.4	10409.4
85	5124.2	11683.2	31705.1	21430.6	88176.8
86	361.8	825.1	2140.0	780.7	4591.6
87	663.7	1513.2	3966.9	1341.7	8465.4
88	808.7	1844.0	2269.2	5100.7	10578.0
95	2217.9	5056.8	13704.7	7330.7	35688.9
104	162.2	369.9	959.4	350.0	2058.5
105	859.5	1959.8	5082.9	1854.3	10906.0
106	181.3	413.4	1160.4	203.0	2393.4
110	488.2	1113.1	1369.8	3079.1	6385.6
118	311.2	709.6	873.3	1963.0	4071.0
131	7209.9	16438.5	42853.4	29677.8	120629.5
134	129.4	295.0	765.3	279.1	1642.0
135	634.0	1445.5	3808.4	1241.4	8106.7
136	30.8	70.2	197.2	34.5	406.8
141	4878.1	11122.1	30142.8	16123.4	78495.5
144	373.4	851.5	1392.5	1691.9	5142.1
156	4173.6	9515.8	24978.2	17226.1	70164.8
160	630.9	1438.6	3731.2	1361.2	8005.8

figures, numbers of individual residences, construction costs and other parametric information. Emission factors were available in AP-42.

Off-highway unregistered motorcycles were assumed to be 18 percent of those registered within the county. Usage was then assumed to be uniformly distributed over the grids within the counties, in proportion to grid population.

For lawn and garden equipment, an average number of operating days (190) was derived from local climatological data. Emissions were apportioned to the twelve counties in the AQCR on the basis of housing units per county. Within the county, grid square emissions were also apportioned on the basis of housing units per grid.

Emissions from construction equipment were apportioned by the dollar value of construction volume on the state level, by population to counties, and by construction area on the grid level. Industrial equipment was distributed only over grid squares containing industrial plants, farm equipment by farm acreage which was estimated for each grid square. Outboard motor boat emissions were distributed over grid squares having navigable water surfaces.

Emissions were temporally distributed over the year to reflect diurnal and seasonal variation of usage. To accomplish this end, each equipment category was assigned an annual operating pattern which was felt to most closely approximate real-life use during a calendar year. The operating patterns assumed were as follows:

Off-highway motorcycles	March through October	9 AM - 7 PM
Lawn and garden equipment	April through September	9 AM - 7 PM
Construction equipment	March through October	6 AM - 6 PM
Industrial equipment	Year round	8 AM - 6 PM
Farm equipment	March through October	5 AM - 7 PM
Outboard motors	April through September	9 AM - 7 PM

A typical printout is shown in Table 36.

4.8 FUGITIVE DUST EMISSIONS INVENTORY

As part of the RAPS a methodology was developed to calculate an hourly

TABLE 36. SAMPLE OF EMISSIONS FROM OFF-HIGHWAY MOBILE SOURCES

GRID NO.	POLT	M-CYCL	LWN&GDN	FRM EQ	CONSTR	IND EQ	OUTBD	TOTAL
1	HC	8.6717+01	4.7226+02	7.1841+03	1.3690+03	0.0000	0.0000	9.1120+03
	CO	1.6601+02	3.6794+03	8.3016+04	1.4099+04	0.0000	0.0000	1.0096+05
	NOX	7.0311-01	3.6140+01	1.2173+04	9.1491+03	0.0000	0.0000	2.1361+04
	PART	1.1718+00	9.7593+00	1.4408+03	6.9642+02	0.0000	0.0000	2.1482+03
	SOX	2.5390-01	2.4679+00	9.4990+02	7.1008+02	0.0000	0.0000	1.6627+03
2	HC	8.4603+01	4.5485+02	7.1841+03	1.4248+03	0.0000	0.0000	9.1484+03
	CO	1.6197+02	3.5437+03	8.3016+04	1.4675+04	0.0000	0.0000	1.0140+05
	NOX	6.8597-01	3.6734+01	1.2173+04	9.5225+03	0.0000	0.0000	2.1733+04
	PART	1.1433+00	9.3995+00	1.4408+03	7.2485+02	0.0000	0.0000	2.1762+03
	SOX	2.4771-01	2.3769+00	9.4990+02	7.3906+02	0.0000	0.0000	1.6916+03
3	HC	1.3729+02	7.1818+02	7.1841+03	1.4528+03	2.8312+02	0.0000	9.7754+03
	CO	2.6282+02	5.5953+03	8.3016+04	1.4962+04	7.4375+03	0.0000	1.1127+05
	NOX	1.1131+00	5.8000+01	1.2173+04	9.7092+03	1.1312+03	0.0000	2.3073+04
	PART	1.8552+00	1.4841+01	1.4408+03	7.3906+02	7.9375+01	0.0000	2.2759+03
	SOX	4.0197-01	3.7530+00	9.4990+02	7.5355+02	7.2500+01	0.0000	1.7801+03
4	HC	2.3740+01	1.3275+02	1.7960+03	2.1419+02	0.0000	5.3770+03	7.5457+03
	CO	4.9277+01	1.0343+03	2.0754+04	2.2060+03	0.0000	1.5930+04	3.9974+04
	NOX	2.0870-01	1.0721+01	3.0433+03	1.4315+03	0.0000	3.1462+01	4.5171+03
	PART	3.4783-01	2.7434+00	3.6020+02	1.0896+02	0.0000	0.0000	4.7226+02
	SOX	7.5364-02	6.9373-01	2.3747+02	1.1110+02	0.0000	3.0759+01	3.8010+02
5	HC	6.9774+01	4.0044+02	1.7960+03	4.2838+02	0.0000	0.0000	2.6946+03
	CO	1.3353+02	3.1178+03	2.0754+04	4.4120+03	0.0000	0.0000	2.8419+04
	NOX	5.6573-01	3.2340+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9391+03
	PART	9.4289-01	8.2781+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8735+02
	SOX	2.0429-01	2.0926+00	2.3747+02	2.2220+02	0.0000	0.0000	4.6197+02
6	HC	3.4328+01	1.7410+02	1.7960+03	4.2838+02	0.0000	0.0000	2.4328+03
	CO	6.5718+01	1.3564+03	2.0754+04	4.4120+03	0.0000	0.0000	2.6588+04
	NOX	2.7833-01	1.4061+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9206+03
	PART	4.6389-01	3.5979+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8219+02
	SOX	1.0051-01	9.0981-01	2.3747+02	2.2220+02	0.0000	0.0000	4.6069+02
7	HC	3.4328+01	1.7410+02	1.7960+03	4.2838+02	0.0000	0.0000	2.4328+03
	CO	6.5718+01	1.3564+03	2.0754+04	4.4120+03	0.0000	0.0000	2.6588+04
	NOX	2.7833-01	1.4061+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9206+03
	PART	4.6389-01	3.5979+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8219+02
	SOX	1.0051-01	9.0981-01	2.3747+02	2.2220+02	0.0000	0.0000	4.6069+02
8	HC	3.4328+01	1.7410+02	1.7960+03	4.2838+02	0.0000	0.0000	2.4328+03
	CO	6.5718+01	1.3564+03	2.0754+04	4.4120+03	0.0000	0.0000	2.6588+04
	NOX	2.7833-01	1.4061+01	3.0433+03	2.8630+03	0.0000	0.0000	5.9206+03
	PART	4.6389-01	3.5979+00	3.6020+02	2.1793+02	0.0000	0.0000	5.8219+02
	SOX	1.0051-01	9.0981-01	2.3747+02	2.2220+02	0.0000	0.0000	4.6069+02

M-CYCL : OFF HIWAY MOTORCYCLES
LWN&GDN: LAWN & GARDEN EQUIPMENT
FRM EQ : FARM EQUIPMENT
CONSTR : CONSTRUCTION EQUIPMENT
IND EQ : INDUSTRIAL EQUIPMENT
OUTBD : OUTBOARD MOTORS
UNITS : KG/YR

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fugitive dust emission inventory for the Metropolitan St. Louis Air Quality Control Region (29).

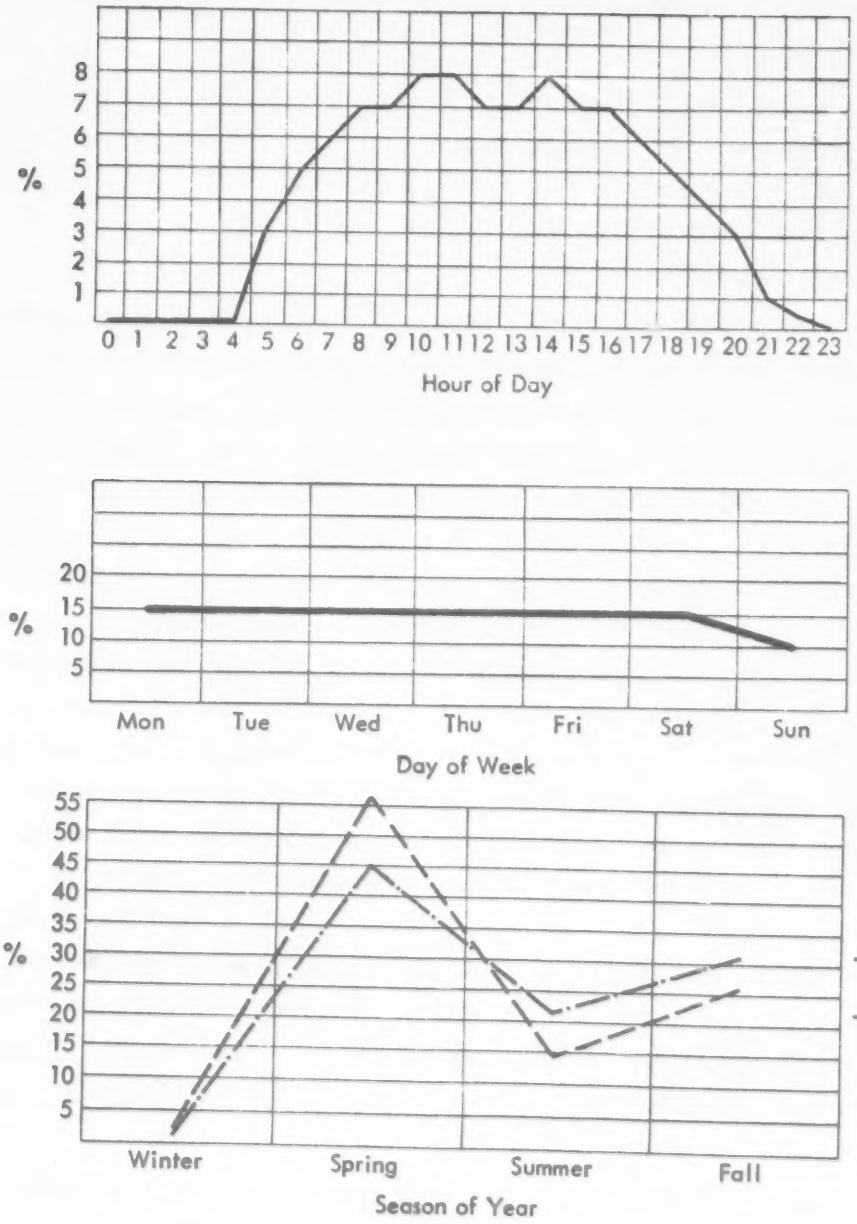
The following six categories of fugitive dust sources were addressed:

1. Unpaved roads;
2. Agricultural land tilling;
3. Wind erosion of agricultural land;
4. Construction sites;
5. Aggregate storage piles; and
6. Unpaved airstrips.

For each of 1989 RAPS grid areas, data were compiled on annual emissions of fugitive dust. This required, in addition to basic emission factors adjusted for local climatic and surface conditions, annual measures of source extent for each grid area. For unpaved roads, vehicle-miles traveled were estimated for each grid containing unpaved roads. For agricultural land tilling the acreage of harvested crops for five major crops (corn, soybeans, wheat, milo and hay) was determined for each grid square. Wind erosion of agricultural land is proportional to the average exposed (unvegetated) acreage, which was assumed to be vulnerable to wind erosion from the time of primary tilling to about 1 month after planting. Fugitive dust emissions from construction sites are directly related to the land area being worked, over a specific time period, therefore, annual acres of construction for each grid square were determined. Emissions from aggregate storage are proportional to the quantity of aggregate stored, therefore, the quantity of aggregate stored annually within each grid is determined. Dust emissions from unpaved airstrips was estimated from the number of landing/takeoff cycles. Finally, hourly apportioning factors were derived to account for emission variation by hour of the day, day of the week, and season of the year. The temporal apportioning factors for agricultural tilling are shown in Figure 18.

The basic emission factor equations were developed as part of EPA's emission factor development program (30). These factors refer to dust particles smaller than 30 microns in diameter, the approximate effective cut-off diameter of a standard high-volume sampler (based on a particle density of 2.5 g/cm^3).

Source Type: Agricultural Tilling



Percentage of total daily, weekly, and annual agricultural tilling

FIGURE 18. TEMPORAL APPORTIONING FACTORS

Available retrievals include temporal apportioning factors, county totals of annual source extent and annual emissions for each source category. (Table 37).

TABLE 37. SUMMARY OF ANNUAL EMISSIONS OF FUGITIVE DUST

State	County	Emission rate (tons/year)						
		Unpaved roads	Agricultural tilling	Wind erosion	Construction	Aggregate storage	Unpaved airstrips	Total
Illinois	Bond	46,594	5,612	44,186	1,716	0	7.8	98,115
	Clinton	56,874	7,804	62,665	3,048	5.2	39.1	130,435
	Madison	69,509	8,796	80,865	19,680	12.2	70.4	178,932
	Monroe	21,338	4,852	42,542	1,812	7.7	174.6	70,726
	Randolph	50,431	6,132	50,896	3,996	45.4	10.9	111,511
	St. Clair	62,286	9,509	77,950	21,120	313.5	133.0	171,311
	Washington	57,524	9,115	70,846	1,044	16.5	3.9	138,549
	Subtotal	364,556	51,820	429,950	52,416	400.5	439.7	899,582
Missouri	Franklin	44,721	3,750	20,089	5,220	6.3	0	73,788
	Jefferson	18,478	678	5,436	12,765	215.8	33.6	37,606
	St. Charles	19,818	2,478	39,607	9,901	57.0	9.8	71,870
	St. Louis City	0	0	0	3,256	0	0	3,256
	St. Louis	0	1,395	11,749	45,491	323.9	0	58,958
	Subtotal	83,017	8,303	76,881	76,633	603.0	43.4	245,478
	Total	447,573	60,123	506,831	129,049	1,003.5	483.1	1,145,058

5.0 SUMMARY

The goal of the emission inventory for the Regional Air Pollution Study at St. Louis was an ambitious one: to produce a high resolution inventory for AQCR 70 for all pollutants of interest. This goal has been largely achieved.

The RAPS emission inventory have been arranged in a uniform format and stored on EPA's Univac 1110 computer at Research Triangle Park, NC. The following inventory data are available for the St. Louis area:

A. Point Sources

1) Criteria Pollutants - TSP, SO_x, NO_x, THC, CO
2) Hydrocarbon breakdown
3) Non-Criteria Pollutants
4) Heat
5) Sulfur trioxide
6) Particle Size Distribution

B. Area Sources

1) Criteria Pollutants - TSP, SO_x, NO_x, THC, CO
2) Hydrocarbon Breakdown
3) Heat

Hourly values are obtainable for all point sources in excess of 10 tons per year (in some cases 1 ton per year). Location of point sources on UTM coordinates (Zone 15) are available to $\pm$ 10 m. Area sources are assigned to a network of grid squares of variable size.

This data base, which contains complete information for 1975 and 1976 complements the RAMS (ambient) data collected over the same period. Together, they form an extensive, accurate data base suitable for many uses in the field of air pollution modeling and control.

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